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Control of Animal Parasites

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Control

OF

Animal Parasites

General Principles and Their Application

By

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Washington, D. C.

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Preface

In this volume the subject of parasite control is presented on the basis of a series of diagrams and analyses of these diagrams in terms of military science. The diagrams present in visual form the factors in our problems of control, covering the life histories of parasites as lines of communication between infested hosts and susceptible host animals, together with a representation of weapons available for direct attack on the parasite in or on its host animal and for cutting the lines of communication between infested and susceptible host animals. This visual presentation is compact to an extent not readily attained otherwise. The control of parasites is treated as a form of warfare, and a body of formulated military principles has been used in this book in analyzing our control problems. This procedure, while novel, proves to be extremely useful, and the writer, with 30 years' experience in parasitology, has found that this method of dealing with parasite problems develops the facts in a situation, indicates the strength and weakness of our position, and shows what should be done much better than do the casual methods of attacking problems with which he is familiar and which are customarily employed.

Parasitology is both a pure and applied science. It is precisely at the point of application of the findings of pure science to parasite control that we encounter special difficulties, and it is at this point that the methodology used in this booklet is of value. Experience shows that the laboratory scientist is not always a good field marshal, and that he lacks in many cases the basic knowledge of topography, climatology, farm practice and other things essential in translating laboratory findings into control measures for parasites. The practicing veterinarian and physician are usually weak in regard to the body of knowledge developed in the laboratory. In all cases the lack of knowledge probably results in the waste of large sums of money on campaigns which could be

shown, by the methods employed in this book, to be fore-doomed to failure before they began. All of these groups could employ to advantage the principles developed by men of military genius in making an estimate of a situation and apply the strategical and tactical principles of warfare to the resolution of the problem in hand. The fact that one can dramatize a problem in parasite control as a form of warfare is an advantage, not a disadvantage, in dealing with legislators, administrators, farmers, patients and others who must be consulted and interested.

The writer regards parasite control as a special subject deserving special study and on a par in this respect with morphology, pathology and similar subjects. This book is the first book devoted entirely to a consideration of the basic principles of parasite control. It is not exhaustive in its treatment, but is intended as a suggestive treatise for the use of the parasitologists, veterinarians and physicians who deal with the control of parasites of man and other animals, and of veterinary and medical students who are studying the subject of parasite control.

MAURICE C. HALL.

Washington, D. C., February, 1936.

Strategy and Tactics

"I ask for the man whom I can hate, for the priest whom I can believe, and for the woman I can love." Guivric in *The Silver Stallion* (James Branch Cabell).

As the above quotation implies, war, religion and love have been the outstanding interests of mankind beyond the satisfaction of hunger, but man's interest in war is probably not conditioned by his hatred of others any more than by his love of fighting. Professional soldiers quite generally, and volunteers and amateurs not infrequently, expend little or no adrenal secretion in hatred of an enemy, and generals in particular cannot afford the bias of excitement and hate in battle.

There is no need that the savor should go from our lives because of a lack of fighting, even though the preposterous game of human warfare be discontinued. The human race has enemies enough to keep it busy for centuries, and the world's greatest battles have not yet been fought. The war against disease is hardly begun, in spite of the fact that mankind has engaged in skirmishes on a thousand fronts against this enemy for many thousands of years. One aspect of the war on disease, namely, the war on worm parasites, received little attention until about 1881, at which time hookworm disease began to attract attention. At the present time there is a growing interest in the war on parasites, but there is still very little in the way of serious warfare with adequate forces and with the employment of comprehensive tactics and strategy.

Many of the forces in the warfare on parasites are more or less unconscious of the existence of other forces, and there is very little coordination of effort. Many potential forces are uninterested in the war as such, and uninformed as to strategy and tactics. This manual is an attempt to present the picture of the war and to outline its strategy and tactics in such a way that all forces may be made more conscious of their relationships and of the possible measures which may be taken to defeat our parasite enemies. It is also an attempt to supply to young officers a comprehensive method of planning campaigns and fighting battles.

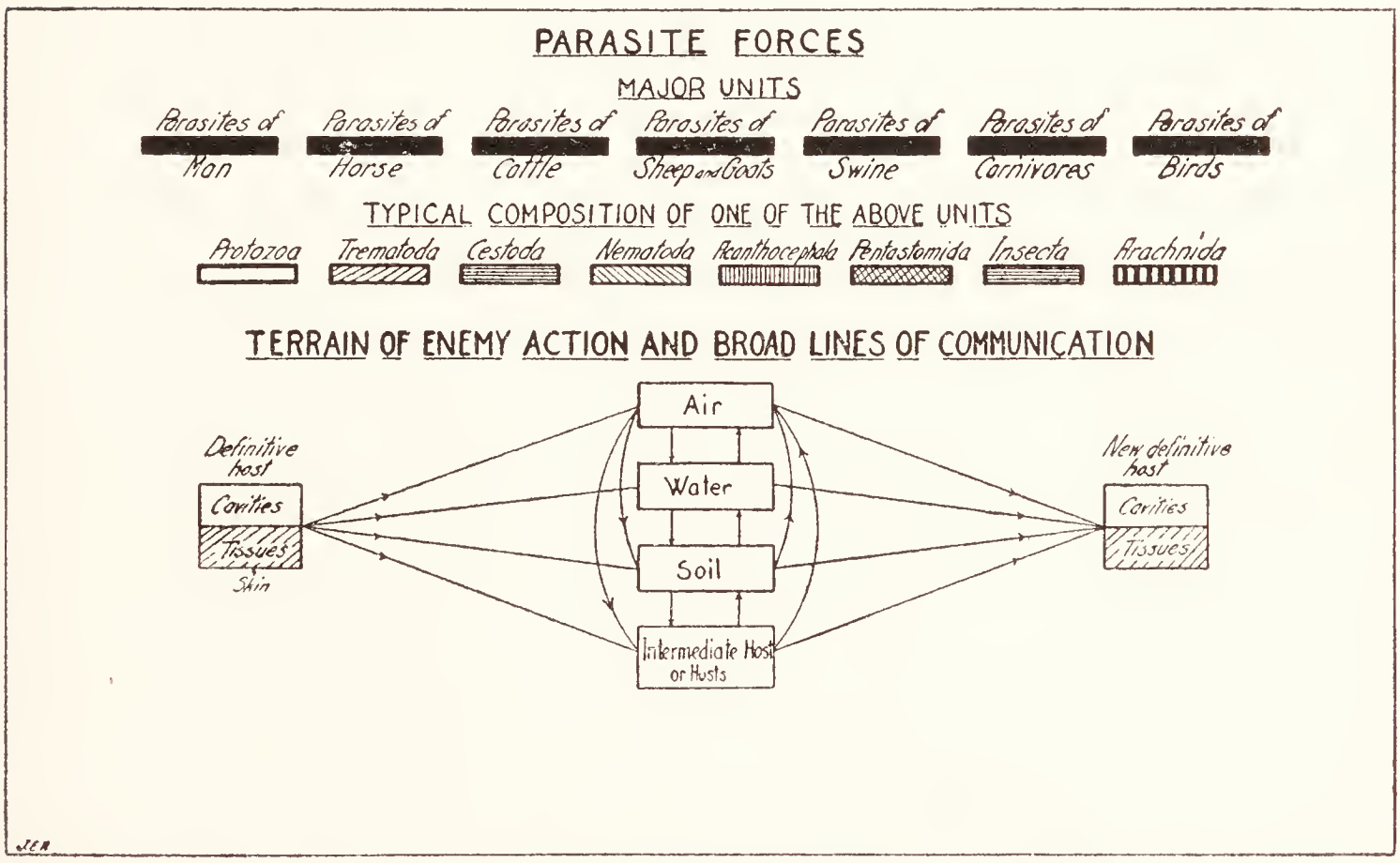
In a number of papers (Hall, 1924, 1928, 1932), the writer has discussed parasite problems in terms selected from military terminology. This terminology is appropriate because the fight

with and the destruction of hostile forces, whether human, verminous, insect, or bacterial, is war. Methods of conducting war have been studied by military men for thousands of years, and the principles laid down by a Caesar, Napoleon, Clausewitz or Jomini are often as applicable in a war on parasites as in a war between nations. So far as the writer is aware, tactics and strategy have been almost exclusively the interest of military men, perhaps on the assumption that these subjects had no application except in human warfare, or that they were an inscrutable form of arcana, or for some other reason. It is here proposed to indicate the value and application of the military principles of tactics and strategy in the war on parasites. All the parallels between human war and war on parasites cannot be drawn with equal closeness, and there will be variation in the parallels drawn, but, in general, the principles stand.

The Nature of the War on Parasites

Enemy Forces

The enemy forces with which we are concerned in the war on parasites are divided into 7 major groups, of which 6 large groups are of major importance, and 1 small group, the Pentastomida (regarded by some as a degenerate anthropod group), is of minor importance. These groups are as follows: 1. Protozoa; 2. Trematoda; 3. Cestoda; 4. Nematoda; 5. Acanthocephala; 6. Pentastomida; 7. Arthropoda. These groups are united for purposes of attack into armies designated by their area of operations, of



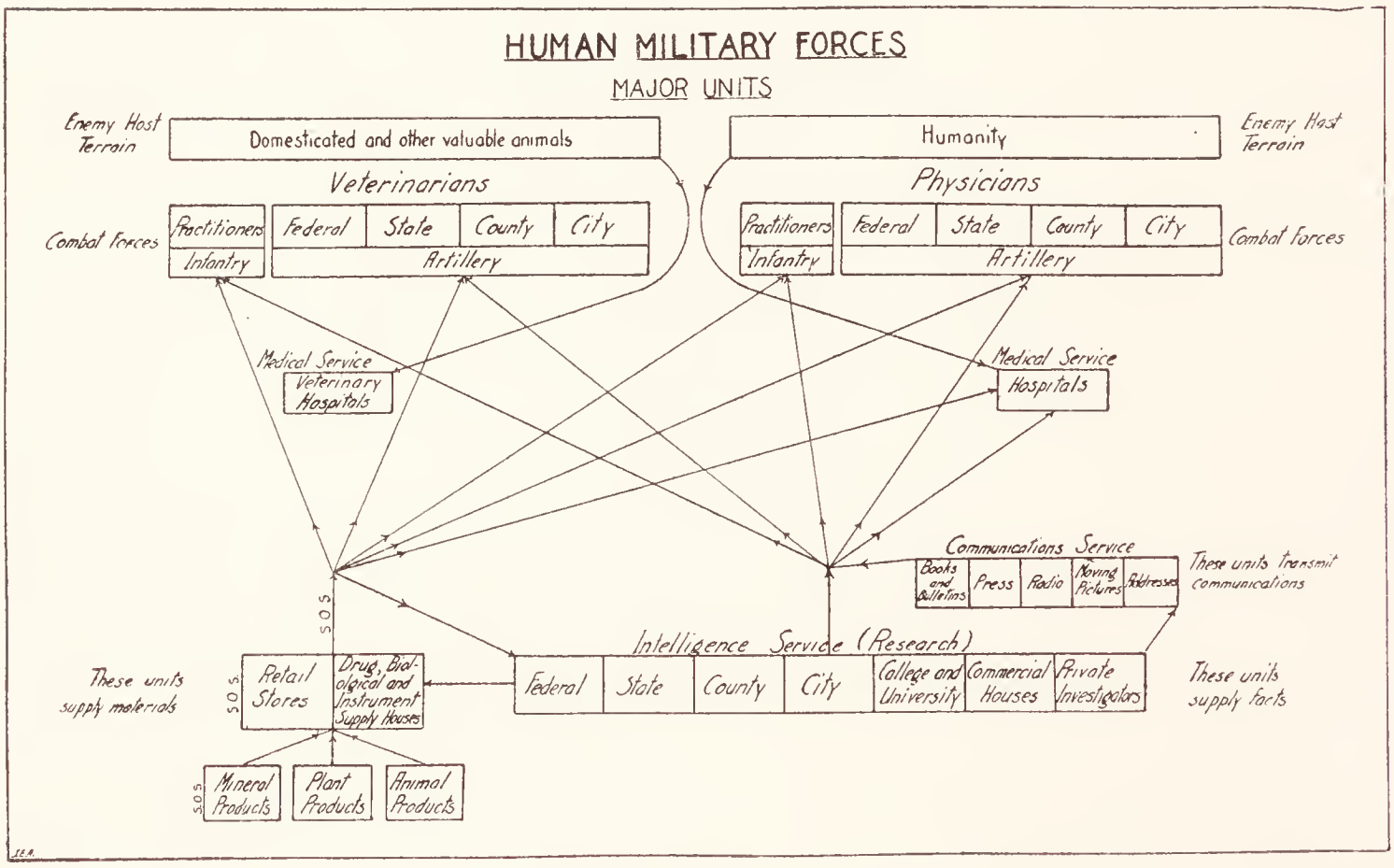
which the most important to us are the following: Parasites of Man, Parasites of Horses, Parasites of Cattle, Parasites of Sheep and Goats, Parasites of Swine, Parasites of Carnivores, and Parasites of Birds.

Organization of Our Forces

The existence of forces adequate in number and suitable in kind for carrying on a war is a basic essential for success. These forces include Diplomatic Forces for the formulation and enactment of laws, for the forming of alliances, and for other elements

of grand strategy directed toward the furthering of our cause, and Combat Forces for attacking an enemy, and coordinated units necessary in combat. The forces may be listed as: 1. Diplomatic Forces; 2. Combat Forces; 3. Service of Supplies (S. O. S.); 4. Intelligence Service; and 5. Communications Service. The nature of each of these services is discussed below.

1. The Diplomatic Service deals with the human and legalistic aspects of parasite warfare as opposed to the zoological and medical aspects. The executive, legislative and judicial branches of national, state, county and city governments are involved in the war on parasites in such ways as the following: By passing laws establishing quarantines to keep parasite enemies out of uninvaded areas; by passing laws requiring that the presence of enemies be reported to governmental authorities; by passing laws providing that when citizens are found harboring parasitic enemies on areas controlled by them, these citizens may be drafted for service against these enemies; and by enforcing such laws.



The Diplomatic Forces of mankind have been enlisted only to a very slight extent in the war on parasites. A really adequate provision would call for international agreements to prevent the passage of parasitic enemies from country to country, but very little of this international control is possible at present. There is

some control in the way of national quarantine and regulation, but this power must be exercised with discretion, since it is only too easy to interfere with our own and our allies' interests in international travel, trade and friendly relations to an extent for which the damage to the parasitic enemy would not be compensation (See Hall, 1933). Furthermore, we have as yet no adequate and rapid means for detecting and identifying many of the worst of our enemies, and it would be impracticable to keep out all enemies without stopping international trade in livestock.

The most effective use of Diplomatic Forces in a war on parasites in the United States, or the world, up to the present time, is in the campaign against the cattle fever parasites and cattle fever ticks, a campaign that will be discussed in detail as a model of its kind. A similar campaign against sheep scab has not been equally effective for the reason that the diplomatic aspects of the war have not been taken care of so effectively as in the tick campaign. Adequate laws and quarantine regulations have not been provided and enforced over part of the United States, and in the area where this is true the campaign against sheep scab has degenerated into a guerrilla warfare lasting for years and involving much wasted effort. (See Hall, 1931). Where the Diplomatic Forces have functioned effectively, the Combat Forces have been brilliantly successful against the scab mite; where political selections and political action have taken precedence over professional selections and professional action, little has been accomplished.

2. The Combat Forces in the wars against parasites are mostly medical men, physicians in the war against Parasites of Man, and veterinarians in the battles against parasites attacking domesticated animals. In such countries as the United States, these Combat Forces are mostly practitioners so far as the direct attack on parasites is concerned. In countries where there are few or no practioners, as in many parts of the tropics, the corresponding Combat Forces are governmental forces comprising the "regular army" engaged in the warfare on parasites at all times. In the U. S. S. R. the Combat Forces are exclusively governmental forces. These Combat Forces engaged on the front line of the occupied host terrain, whose business is to drive the enemy from his position, defeat and, if possible, annihilate him, and hold the position against counter attack, constitute the infantry.

Backing up the infantry attack is an artillery attack utilizing

sanitation and similar weapons intended to cut the enemy lines of communication, cut off his reinforcements, defeat his allies, destroy his supplies, and in general to attack him in all places other than the occupied host terrain. The forces that engage in this artillery action are usually governmental but there are also practitioners, extension services and others who take part in this, and these forces work in many cases in close association with the Diplomatic Forces.

3. The Service of Supplies brings up ammunition and supplies from the base to the combat troops and other units. This service consists of the commercial houses supplying drugs, chemicals, biologics, and instruments used in the war on parasites. The lines of the S. O. S. go back to the plants of the tropics for quinine, and into the depths of the earth for arsenic and other metals. The S. O. S. is an essential service, not spectacular but immensely important.

4. The Intelligence Service is the group which directs raids on the enemy, identifies captives and the units to which they belong, observes and reports signs of enemy activities, ascertains enemy habits, weapons, strategy and tactics, finds the weak spots in the enemy ranks and the vulnerable points in their lines of communication, and develops the weapons for destroying them and cutting their lines of communication. The forces in the Intelligence Service are mostly governmental in the United States, but there are also a considerable force of intelligence officers in the academic group of universities and colleges, a few officers in research laboratories of commercial houses, and a few practitioners and other volunteers not connected with the above groups.

5. The Service of Communications is the service which maintains communication between different units, carrying reports of the fighting from the Combat Forces to other forces, reports of new enemies, new enemy movements, and other information from the Intelligence Service to other groups, and in general facilitating communication and facilitating cooperation. In this service are the Extension Services, the writers and publishers of scientific and professional books, periodicals, bulletins, and other publications, of the popular magazines and daily press, and the forces of the radio and the movies.

Weapons of Enemy Forces

Our parasitic enemies use a variety of weapons, and attack in

a variety of ways, but for the most part they use the weapons of trauma and poison. At this point we consider only a few more or less typical weapons and modes of attack as a background for a consideration of our tactics and strategy.

Protozoa. Most of the Protozoa invade the host terrain along the route which is the Great Highway of Invasion for parasite enemies, namely, the lumen of the digestive tract, entering unobserved by mixing in the traffic that enters the portal of the mouth and to a large extent taking and holding various points in the lumen of the digestive canal. Rhizopods, flagellates and ciliates invade this territory and occasion damage which has been charged to such weapons as those of traumatic injury and poison.

The most serious damage follows when these enemies leave the lumen of the digestive canal and invade the tissues of the host terrain. Such enemies as the coccidia may invade the walls of the digestive canal, the liver, or other organs, occasioning great traumatic injury. Amebae may invade the walls of the digestive canal, and may enter the liver or the brain. The blackhead organism may enter the liver.

Some Protozoa are conveyed to new host terrains in cooperation with other enemies, such as ectoparasites. Thus trypanosomes may be carried by tse-tse flies or bugs, entering the skin through the wounds made by these ectoparasites, and then navigating the blood streams of the new host terrain, poisoning these streams, and bringing on injury and death. Sarcosporidia invade the muscles and cause traumatic injury.

Trematoda. The trematodes invade host terrain by the mouth or by piercing the skin. They settle in the digestive canal or invade the body cavity, liver, pancreas, air sacs, eyes and other organs, or enter the blood stream through the skin. They attack by trauma, including pressure and irritation, they block ducts and canals, and they may poison their hosts.

Cestoda. The adult tapeworms, as a rule, invade only the digestive canal, but some invade the ducts of the liver and pancreas. These enemies usually have an armed head, ordinarily provided with two or four suckers, and often with a rostellum or suckers armed with sharp hooks, usually more or less sickle-shaped, and these armed heads attach to the intestinal mucosa or cut down through it to deeper layers, sometimes to the serosa. In addition to traumatic injury, the tapeworms may poison man and his domes-

ticated animals; *Diphyllobothrium latum* in man may cause a severe anemia, resembling pernicious anemia, as a result of such a toxic action.

The larval tapeworms invade host terrain when the larvae are tiny enemies armed with six hooks, and they cut their way into tissues and blood vessels with these hooks. As they grow they attack the host tissues by pressure and at times by the hooks on the scoleces of the bladderworms.

Nematoda. The nematodes may injure tissue by biting, as do ascarids, or by means of teeth and other cutting and tearing weapons, as do hookworms. They may burrow into glands or through tissues as do tetrameres, trichinae and many others. They may block the lumen of tubes as do ascarids and heartworms. Some of them appear to be toxic; at any rate they produce severe reactions, sometimes with fever, as in the case of trichinae. They rob us and our allies of food, and some of them suck blood and cause anemia, mental and physical retardation, cachexia, and death. The young worms are provided in many cases with spears by which they enter through the skin or drive into tissues from the lumen of the digestive tract.

Acanthocephala. The thorn-headed worms are armed with many sharp hooks arranged in rows on a proboscis, and this armed proboscis is thrust into the walls of the digestive tract, causing a severe local reaction.

Pentastomida. The pentastomes are armed with hooks and spines, and with these weapons the adults injure the linings of cavities and the larvae injure the tissues which they invade.

Arthropoda. The arthropods have two major parasitic units, the Insecta and Arachnida.

Insecta. The insects attack the skin of host animals with biting or piercing mouth parts, and the attacks may be so savage as to kill. They may damage the wool, mohair or hair coat of our domesticated animals. They may inject poisons of high virulence, producing local or systemic injury. They may invade the body and live in the nostrils or stomach or under the skin, causing grave injury with their armament of hooks and spines. Finally they cooperate with our protozoan and bacterial enemies, carrying them from invaded host terrain to the conquest of new terrain.

Arachnida. The ticks and mites attack with piercing mouth parts, and the mites may burrow into the skin, causing serious

injury and sometimes death. Many ticks cooperate with protozoan enemies in carrying the latter to new terrain in their war of invasion and conquest.

Weapons of Our Forces

Weapons may be either offensive for attack or defensive for protection. Both kinds are given brief consideration at this point. Defensive weapons are usually referred to specifically as armor, fortifications, etc.

Our Diplomatic Service supplies such defensive weapons as quarantine, and such offensive weapons as the legislative compulsion to dip livestock for parasites.

Our infantry weapons of offense for direct attack on the enemy include a vast array of drugs which fall in 3 general categories, the protozoicides, the anthelmintics, and the insecticides. They also include the surgical instruments employed against such enemies as hydatids.

Our artillery weapons are in the nature of sanitary procedures and special measures for cutting the enemy lines of communication and similar purposes. These measures are very numerous and are merely catalogued here for future reference.

Maneuvers and weapons for cutting enemy lines of communication

I. Sanitation
  1. In barns, stables, poultry houses and other structures
    a. General sanitation
      Adequate ventilation and sunlight
      Cleanliness and dryness
      Clean, safe food and water supply
      Raised water troughs and feed racks
      Bathing, currying, grooming, etc.
    b. Safe feces disposal and related maneuvers
      Frequent and thorough removal with shovel, broom and hose
      Use of hot, strong disinfectants
      Use of brine solutions against hookworm larvae on soil
      Plowing under of feces
      Composting of feces

Use of manure box { Self-heating / Steam heated }
Putting poultry, foxes, etc., on wire or hardware cloth
Privies and related objects { Man / Cat }
Septic tanks
Sewerage systems

c. Safe urine disposal
Washing of floors
Disinfectants
Wire screen and hardware cloth
Slat floors

d. Protection against external parasites
Screening
Mosquito nets
Repellents

2. On pastures, paddocks, yards and other areas

a. General sanitation
Light stocking
Pasture rotation
Stock rotation
Hillside pastures
Special safe areas for young stock
Bare lot
Burning over of pastures
Abundant sunlight
Adequate shade, with exposure of shaded area to sunlight during part of day
Utilization of dry areas
Utilization of freezing weather

b. Special sanitation
Isolation of carriers from susceptibles (turkeys from chickens, for gapeworm control)
Swine sanitation
Modified swine sanitation
Elimination of wet or swamp areas
Draining
Filling
Fencing off

Use of shoes and gloves
Milk and dairy inspection
Use of mineral mixtures to prevent pica

II. Control of intermediate hosts
Meat inspection
Cooking food (meat, fish, crabs, etc.)
Snail destruction
- Swamp elimination
- Use of chemicals
  - Copper sulphate
  - Lime
- Use of frogs, toads, carp, etc.

Earthworm destruction
Use of chemicals
Use of sand
Insect destruction
Use of chemicals
- Contact insecticides
- Stomach poisons

Destruction of breeding places
- Draining
- Safe manure disposal

Tick destruction
Use of chemicals (dipping)
Use of starvation (pasture rotation)

The best defense is sometimes an offensive, and some of our defensive weapons are also offensive weapons. Our defensive weapons and armaments include: (1) Those provided by nature, such as immunity (active and passive), resistance and tolerance; (2) tonic and sustaining treatment, such as the provision of nourishing food, safe water, salts, minerals, vitamins, tonics, etc.; and (3) the artillery barrage cutting off enemy reinforcements.

Tactics and Strategy of Warfare on Parasites*

Strategy is the science of employing the different branches of the art of war for formulating operations and directing military movements, including moving troops in such a way as to give battle with decisive results. It operates at all times, but during battle tactics becomes the primary consideration.

Tactics is the use of military forces to gain victory in battle. Battle is the logical culmination of military strategy. The application of tactical principles is the art of fighting.

Strategy

Diplomacy and the military forces conjoin in grand strategy. In the war on parasites, diplomacy deals with the involved human, legalistic and non-medical elements such as legislators, stockmen, farmers, markets, etc. Diplomatic strategy operates in peace and war.

Strategy answers the questions: What is our purpose or mission? What should we do to accomplish our mission? How should we do it? When should we do it? It is a more inclusive term than tactics. At battle, strategy merges into tactics. Strategic success must make use of tactical victory.

Strategy involves: Items of position, lines of supply, terrain, geography, and climate used to our own advantage, in addition to material and moral means. Human opponents and their conduct are limited and restrained, to a certain extent, by human laws and rules, but parasites and our conduct towards parasites are limited and restrained only by natural laws. Indecisive battles are of little value to strategy, and except for the few cases such as tick eradication, or control of *Haemonchus contortus,* our control measures as applied have been indecisive and hence of little strategic value. In strategy there is no victory; it is continuous at all times in its efforts for our welfare and success. We should offer battle only with the chances of success on our side. The

*The writer is indebted to Capt. G. J. Meyers, U. S. N., author of *Strategy* (Byron S. Adams, publisher), for permission to quote from that work. He is also indebted to Col. P. S. Bond, U. S. A., author of *Tactics* (National Service Publishing Co., publisher and owner of copyright), for permission to abstract part of that work and to quote from it. The writer is also especially indebted to Col. Bond for his courtesy in reading and commenting on the section on strategy and tactics, and for helpful suggestions in this connection.

destruction of enemy forces is the ultimate mission of all military strategy and tactics. It is the thing of greatest advantage. Advantages gained must be held. Victory must be followed up by quick pursuit and exploitation. Time always works to nullify our success; suspending an attack on parasites is followed by the rebuilding of parasite strength by new recruits.

Meyers (1928) lays down the following principles of strategy:

1. There must be a head clothed with the authority and charged with the responsibility of stating the purpose to be achieved by each task group in order that intelligent direction may be given to the effort to be applied.

2. There must be a well-defined purpose in any operation of war, measured by its value to the purpose of the war and by the effort it will cost in its attainment.

3. There must be forces adequate to achieve the purpose in view; the forces must not be allowed to fall below the standard fixed strength in men, material, and morale.

4. The forces provided must be of arms or types suitable to the terrain and equipped with weapons for overcoming those of the enemy.

5. Dispositions must be made in time to gain for us advantages which will further success; they should provide against interruption of supplies to the combat forces.

6. There must be constantly an evaluation of the situation, an inspection of preparation, means and progress, and a study for improvement or alteration in means, plan and disposition as may be found necessary to further success.

Tactics

Tactics, to be practical and successful, must be simple. Tactics is practical rather than theoretical. The infantry is the dominant arm of the service, and the function of all other arms is to assist the operations of the infantry. In actual combat with parasites of livestock, the practicing veterinarians are the infantry, the dominant battle factor. Great battles are made up of the small combats of infantry platoons. Their local successes are the components of great victories and of wars won. The leader of the infantry platoon is the most important man in the army, and the veterinarian the most important man in the war on livestock

parasites as far as battle tactics are concerned. This is not the case as regards the strategy of parasite campaigns, in which matter organized state forces are usually more important, and in which the Intelligence Service is much more important at this time in planning campaigns which can not be carried out until their work is done.

Organization is necessary to make possible the employment of the nation's resources, to mold men and material into a weapon of the government. Organization is essential to nearly all human achievement. An army must have organization, training, discipline, and equipment. These are of almost equal importance, but organization comes first. For most parasite campaigns we have as yet almost no organization. Without that organization, effective campaigns against parasites are usually impossible.

General Procedure of Battle

All combats are the attack on and defence of a position. Parasites defend their positions in hosts, on pastures, and elsewhere. Captured territory as an objective in parasite warfare usually involves the destruction of the hostile army, contrary to what might be true of a human army. The continual surrender of territory must end in the defeat of any enemy; this is true of parasitic enemies. Attacks are made at weak points in enemy positions. Surprise is valuable in human warfare but not, as a rule, in war on parasites; it may be of value in attacks on certain external parasites.

Attacks are by *fire* and by *movement*. Fire superiority is the feature in which our combat forces excel the parasite forces. Movement is the feature in which parasites excel. They move by air, land, and water and in primary and intermediate hosts, over exceptionally varied lines.

Artillery in human warfare fires on enemy artillery, known or supposed positions of enemy infantry, on routes of enemy movement or on enemy groups. In parasite warfare our artillery is usually laid on enemy lines of march or communication or on the extraparasitic enemy groups, such as parasite eggs and larvae. It is impossible, usually, in human warfare, to "shoot the enemy out of his position" and it is rarely possible to shoot the parasite enemy out of his host position by the use of such weapons as anthelmintics or insecticides. It is usually necessary to take the

enemy position on pastures, in barns, and elsewhere, in addition. The enemy counterattacks at the first opportunity; thus hookworms retake the host position from which they have been driven by anthelmintics unless their reserves on the soil terrain are cut off by sanitation. Infantry endeavors to envelop or surround the hostile areas of resistance; these hostile areas may be in host or field terrain, and in field terrain their envelopment usually requires artillery support.

When the enemy is demoralized or retreating is the time to push the attack to victory. Here is where most campaigns against parasites fail. The first easy positions are taken, and the enemy is allowed to come back later for lack of proper exploitation of the initial advantage. A too rapid advance invites trouble if artillery and reserves cannot be brought up and lines of communication established. Hookworm campaigns with only an infantry attack on parasites in their host positions may gain so much ground that the artillery of sanitation is not brought up in sufficient force to prevent enemy counterattacks from regaining much of the lost territory.

Tactical Instruction

Constant training in warfare of any kind is essential for victory. Normal formations and rules must be established, but the officer and soldier must be able to make adaptations of these to fit actual situations. The diagrams in subsequent sections show the usual formation and specific adaptations. There may be several correct solutions of problems; there are usually many incorrect solutions.

A simple tactical problem in parasite control for solution will include: 1. The season of the year and sometimes time of day; 2. detailed information on terrain and other special conditions; 3. strength, composition, and distribution of available forces; 4. detailed information in regard to enemy; 5. strength and location of friendly troops near by; 6. orders and messages received.

STRUCTURE OF TACTICAL PROBLEMS

A solution for a problem includes: 1. The commander's estimate of the situation; 2. his decision or instructions briefly expressed; 3. his definite plan of action, based on his decision; 4. his orders to his command; 5. any messages sent by the commander; 6. any action taken by the commander in addition, such as conferences,

ordering reconnaissance, etc. Details regarding these 6 points are:

1. The estimate of situation is as follows: 1. *The mission* (What is to be accomplished?); 2. *The enemy* (All that may be known or reasonably inferred about him); 3. *Our own forces* (Immediate command and support); 4. *Conditions favorable and unfavorable* (Terrain [very important], season, weather, time of day, etc.); 5. *Courses open* (Various methods of accomplishing mission, with analyses of advantages and disadvantages); 6. *The decision* (A brief statement of the course of action determined upon); and 7. *The plan* (Detailed statement of part to be played by each element of the command).

Or, more briefly, this may be put: 1. What is the task (mission)? 2. What are the enemies, difficulties, or obstacles? 3. What are the facilities and favorable conditions? 4. How do we accomplish our mission?

The mission. This is the most important consideration, forming the basis of all plans and action, whether large-scale and general, or small-scale and detailed. It should be very clear. Orders must not be so detailed as to befog the real mission.

The enemy. We must know the enemy strength and composition, his weapons, his position, his tactical methods, and his recent actions from which his intentions for the future can be derived. Bond states: "It should never be assumed that the enemy will remain inactive," and "It should be assumed that he will act with good judgment," i.e., take the course most embarrassing to us.

Our forces. Our information about our forces should be complete and accurate, covering their strength, armament and location.

Conditions. Terrain is important for the enemy as cover, and as affording facilties for our maneuver and deployment, as a field of fire, etc. Keep a sense of proportion here and elsewhere.

Courses of action. Of two or more courses of action equally promising as regards success, select the one promising greatest results in case of victory or the least disaster if a failure.

The decision. State the decision briefly and clearly. Ordinarily it is not possible for a commander in parasite warfare to make final and definite decisions in most cases. The war on the cattle

tick is an exception. For such decisions in the United States, Congress must authorize action and other authorities must approve it before authoritative action can be taken, and such authorization is infrequent.

The plan. Set out the plan in detail.

Course of thought. "Always the leader must be thinking." Napoleon said that he reached his decisions by hard thinking and never by intuition.

Officers in charge of campaigns against parasites, and students planning a career in the army engaged in these campaigns, should study strategy and tactics by setting out strategic and tactical problems, and writing out solutions with illustrative diagrams. Student solutions should be submitted to competent officers for criticism, and officers should criticize each other's solutions. The common assumption that officers (parasitologists, veterinarians, physicians and others) need no special training in the military principles of the war on parasites is naive and unsound. The subject is as technical as morphology, pathology or similar subjects. What the writer is attempting here is an elementary treatise on the subject.

Hints for Solution of Tactical Problems

Watch important developments, not trifles. Don't take second-hand information in lieu of first hand. The terrain should influence your plans. Pay attention to: Position; direction; distance; time. Adopt a simple plan and carry it out. Use every element and individual; give precise instruction for all. Take the initiative and keep it. Follow good practice, but be bold and original when you have good reasons for it. Don't straddle. Don't disperse your forces or let them get out of control. Be aggressive, but take precautions. Don't shift your responsibilities, or accept those of others. Watch your subordinates, but don't bother them; if incompetent, relieve them. Don't leave room for misunderstanding. Simple principles are the most important, and simple procedures win battles. Make orders clear; don't go over the heads of subordinate officers; keep spheres of authority, action, and responsibility definite. Tell a man what to do, not "if possible." Give positive, not negative or ambiguous orders.

Orders should cover information about our own and the enemy forces, the general plan of action, detailed instructions, and provide for supplies and for communications to be established. Keep the second in command informed of plans.

The second in command is a subject too often neglected in our Intelligence Service. Many organizations have a head who is the only person informed as to the organization as a whole; if he dies, much is lost in time and effort by a successor who must pick up loose ends and achieve the organization point of view as opposed to the individual point of view. Many organizations fail in developing a strong, competent second in command, and such one-man organizations are likely to have an unhappy experience when the one strong man is gone.

Problems of Attack

1. Intelligence or information. 2. Plans and orders. 3. Concentration of fire. 4. Movement of troops and supplies. 5. Surprise. 6. Deployment. 7. Use fire and movement for attack. 8. Attain coordination, control and direction. 9. Continuity of attack calls for sustained effort to keep advantage. 10. Exploitation. Defeat of the enemy is not enough; we must have a "knock out" to impose our will on the enemy by breaking his resistance through destruction of his forces as armed forces. So we must follow up success by pursuit. 11. Security. Provide against counter attack, and for safe retreat in case of tactical defeat.

Colonel Bond has supplied the following comment on the above:

"Destruction of the enemy forces does not mean the killing of helpless men; it means destroying the hostile force *as a force,* preferably by capture, or by destroying its equipment and dispersing its personnel. In this respect parasite warfare is more relentless and ruthless than human warfare; destruction of the parasite enemy forces means *annihilation,* as complete as possible."

Principles of Offensive Combat

Principles are not rigid, but are adaptable to circumstance. They apply to forces of all sizes. Risks are inherent in warfare. Caution and boldness are essential to success; timidity and foolhardiness are disastrous. Success is the only criterion, and results are all that count.

Intelligence

Our Intelligence Service learns about the enemy from reconnaissance, observation stations, prisoners, and captured materials, and by experiments on captives in hosts and *in vitro.*

Concentration of Forces

Superior force usually implies superior numbers, but other

elements of superiority are quality of troops, morale, training, leadership, and equipment, such as artillery. Above all is the will to conquer. Dispersion of force results from physical separation, obstacles or lack of communication if these prevent cooperation. In our war on parasites our forces are usually dispersed and relatively ineffective. Such campaigns as those against cattle fever ticks, and the horse parasite campaigns in Iowa and Illinois, show the value of coordinated attacks as compared with the usual dispersed efforts.

Deployment should be timely; not premature or delayed. The density of deployment (fighting units [such as men] per unit measurement [such as yards] of front) increases with size of units engaged. Too little density, too little power; too great density, interference with fire power and maneuver.

Fire and Movement

All training aims at the intelligent combination of fire and movement, the two elements of battle.

A continued advance is possible only with superiority of fire. We have superiority of fire in our attack on some parasites, but we do not have this superiority in most cases. We do not yet take war on parasites seriously and we do not enlist a big enough army; when we do, a "continued advance" will be possible. Fire superiority is a matter of *volume, accuracy,* and proper *distribution.* These elements are important either with our infantry attack on parasites by anthelmintics, or with our artillery attack by general or special measures to cut the enemy lines of communication.

Coordination and Control

Coordination is difficult in battle. Hence the hierarchy of command. Each unit must have a commander who is supreme in that unit. All the troops should be under the command of one supreme commander. All commanders must know what is necessary or helpful in regard to general plans. The commander must know at all times the situation in regard to all subordinate units under his command; must be kept informed as to developments; reports are essential.

There should be a General Staff for parasite control in every country and an international Board of Strategy. Area commanders in all units of a country should report to the General Staff. Since no such groups can be formed at this time by legis-

lation, they must be formed by volunteers, and should be if we are to have effective war on parasites.

Each combat unit should have an assigned zone of action. "More attacks go wrong by failure to maintain proper direction than from any other cause," according to Bond. Without a definite halting place (objective), attack is likely to become disorganized. Both the attack with "limited objective" and "without regard to objectives" must be used at times; each has advantages and disadvantages. The first is useful while resistance is strong; the latter useful when the enemy is demoralized and exploitation of victory is possible.

In the War on Parasites we are confined as a rule, to the attack with limited objectives, since our lack of organization and of authority usually makes impossible a general attack with exploitation of every local victory.

Continuity of Attack

In attack, success and defeat are unequal along the line, so that attacks are held up at some points while at others they penetrate deeply. It is seldom wise to reinforce a unit which is held up. Push on where the enemy gives way, not where he resists. Exploit successes with reserves, and break down the resisting units by attacks from flank and rear.

All this is applicable in our War on Parasites. Where we have the forces and weapons we should wage war vigorously. Where we are unable to make headway it is evident that we should detail our intelligence officers to that area, and not send Combat Forces to defeat. To do the latter is the mark of an ineffective commander.

Forms of Attack

Attacks are (1) frontal and (2) enveloping. (1) The frontal is with opposing lines parallel or nearly so, to force back or pierce the enemy line. (2) The enveloping attack attempts to overlap the enemy flank or flanks with converging fire and movement.

Advantages and disadvantages. The frontal attack is simple, speedy and direct; is conservative and involves less risk of disaster to attack; may be very costly and doesn't promise as decisive results. It will force the enemy back if successful, but does not always result in his complete defeat. It doesn't insure fire superiority so well as does the converging and enveloping movement.

The enveloping attack converges effort, gives more promise of success, and is more decisive when successful. The flanks of a defensive position are its weakest parts. Ordinarily it is not practicable to attack a flank directly, and risk a counter attack on an exposed flank; the usual procedure is an oblique movement encircling the flank. The enveloping attack calls for a frontal "holding" attack. The development of both flanks is usually inadvisable. Against an extensive front, the attack as a whole starts as a frontal attack, but when the line of defense is broken each section presents flanks which may be enveloped. Defending forces seek positions where flanks may rest on impassable obstacles, or at least where flanks are easy to defend.

Selecting Flank for Envelopment

1. Against which flank can attack be launched more quickly? Time is important.

2. On which flank is the terrain more favorable to attack and less favorable to defense? Involves considerations of cover for attack, obstacles to movement, observation, field of fire, artillery positions available, nature of defender's preparations, etc.

3. Where is enemy's line of retreat, and from what direction would his reinforcements probably arrive? Defense will retreat sooner if his line of retreat or reinforcement is threatened.

4. In view of terrain and the supporting troops on each side, attacking lines of retreat, etc., which flank involves lesser risk in case of check or reverse?

5. Which flank allows most favorable disposition of attacker's troops?

Pick the better flank, or if equal, the one where most decisive results are promised.

Situations Calling for Frontal Attack

1. With a rolling artillery barrage. 2. On an enemy holding a poorly organized or lightly manned position. 3. To develop (find out about) enemy strength and position. 4. In a rencontré (meeting) engagement; prompt action seizes the initiative.

Problems of Defense

The mission of the defender is to defeat the aims of the attack. Must learn enemy plans, assemble forces to oppose him, use element of surprise in assembling force, etc. Mission is usually not

to advance, but to hold ground; simplifies problems of maneuver, communication, supply, etc. Does not need so much mobility, endurance or training. Passive attitude does not secure decisive results; it is only an interlude in an attack. Usually a vigorous attack is the best defense. Passive resistance is with fire, and active resistance is by counter attack.

Advantages and disadvantages of a defensive attitude. 1. Surrenders initiative to attacker; 2. Moral effect of passive attitude leads to sense of inferiority; 3. No decisive results, even if successful. But— 1. Problems of control, supply, etc., simplified. 2. Does not require so much mobility, training, etc. 3. Can take fuller advantage of nature of terrain. 4. More familiar with terrain.

Organized active defense is organized in depth. Good fortification should not impair mobility; the advantage of fortification is that it enables a wide front to be held by a relatively small force, leaving the bulk of defender's force as a mobile reserve for counter attack, or for use in offensive operations at another locality.

Tactics of Defense

Every combat is the attack and defense of a position, lightly or highly organized. It may be a delaying action, with the place not seriously held, but allowing long range fire on pursuers.

Intelligence

Intelligence is of such importance that every military organization must have it, and in battalions and higher organizations a special unit is organized to *collect, interpret* and *disseminate* it.

To be of value, intelligence must be *fresh, accurate, complete* as possible, *authentic* or its probable credibility indicated, *properly interpreted,* and *arranged for quick reference.* It is of value usually in proportion as it is fresh, *i.e.,* as it indicates an existing condition, not a past and non-existent condition. All this applies to information on parasites.

Principal information required concerns: (1) The enemy; (2) one's own force; (3) the terrain and other conditions.

According to its importance (or application), it is classified as: (1) Important enough to require immediate transmission to higher authority; (2) of value to higher authority, but not important enough for immediate transmission; (3) of immediate interest

only to unit collecting it. No. 1 is transmitted at once; No. 2 at fixed intervals.

Intelligence service comprises officers, non-commissioned chief observers and scouts, observers and scouts of varying grades. The officer directs, collects information, digests, classifies, and transmits information. On contact with the enemy, he (1) makes personal reconnaissance, (2) dispatches patrols, (3) establishes observation posts. The information desired is:

(1) Where is the enemy? Especially, where are his flanks?
(2) What are his strength and the composition of his forces?
(3) What weapons has he?
(4) What works of defense has he?
(5) What is he doing?
(6) What are his probable intentions?

Information obtained chiefly from: (1) Patrols, terrestrial and aerial, (2) observation stations, (3) aerial photos, (4) front line companies, (5) adjacent organizations, (6) prisoners and examination of dead, and (7) captured materials of various sorts.

Intercommunication

Prompt and reliable transmission of intelligence and orders, and coordination are highly important and require an effective system.

The best means of communication is the spoken word, since it affords a positive, two-way communication. The best substitute for conference is the telephone.

All messages should go through a message center (1) to relieve command of responsibility, (2) to insure dispatch of messages, and (3) to afford logical procedure.

Approach to Battle

The commander must determine: (1) Proper direction of advance; (2) rate of advance; (3) maintain contact and intercommunication; (4) provide for reconnaissance of enemy and terrain; (5) provide security during advance; and (6) provide for supply.

General Comment

Not all of the foregoing military material will be made use of by the present writer. It is assumed that interested readers will see possibilities not indicated here, will make their own interpretations, and develop their own strategy and tactics. For the most part, it is hoped that this work will be suggestive, not exhaustive.

This is a large assignment, but we must face these facts and not delude ourselves with the idea that any lesser effort will ever drive out an enemy that attacks on every possible front at every possible opportunity by day or night. These enemies are 100 per cent hostile, there are no non-combatants, and they carry their declaration of war in the egg or embryo in the maternal uterus and in the sporozoites in the oocyst. They stand to throughout 24 hours of the day awaiting the opportunity to attack. For the most part we face them with inadequate weapons, without a commander, without the will to victory, and with too little knowledge of their tactics and strategy to give us the chance of victory that alone would warrant giving battle.

3. *There must be forces adequate to achieve the purpose in view, and these forces must not be allowed to fall below the standard fixed strength in men, material, and morale.*

It must be evident that no large purpose, such as the eradication of any one of many parasites, could be taken as an objective with the present available forces. For the purposes of an attack with a limited objective, such as the capture of host terrain by a veterinary officer, with perhaps some advice to a stockman as to how to hold the terrain, to some extent, against recapture, we have, locally, adequate forces as regards men, material, and morale. For nation- or state-wide campaigns of eradication, or some adequate control, of parasite enemies, we are strategically unprepared.

4. *The forces provided must be of forms or types suitable to the terrain and equipped with weapons for overcoming those of the enemy.*

As already noted, we have no weapons of established value for the destruction of many of the groups in enemy armies, and there is no prospect of victory and no justification for war until the Intelligence Service has developed weapons and ammunition, and devised the detailed tactics and strategy for our operations against these forces.

Eradication of enemy forces over large areas calls for all the forces of diplomacy and the military arms, with such a variety of weapons as will serve in a nation-wide campaign from the cold north to the tropics and from the swamps to the mountains. These weapons we have in large variety, but not yet in sufficient variety for the attack on most parasites.

5. *Disposition must be made in time to gain for us advantages which will further success, providing, among other things, for uninterrupted supplies to combat troops.*

Preparedness is a term easily applied to preparation for international warfare. As regards parasite warfare we need only point out that we are chronically unprepared for the most part, unaware of danger, and uninterested in our defence.

6. *There must be constantly an evaluation of the situation, an inspection of preparation, means and progress, and a study for improvement or alteration in means, plans and dispositions as may be found necessary to further success.*

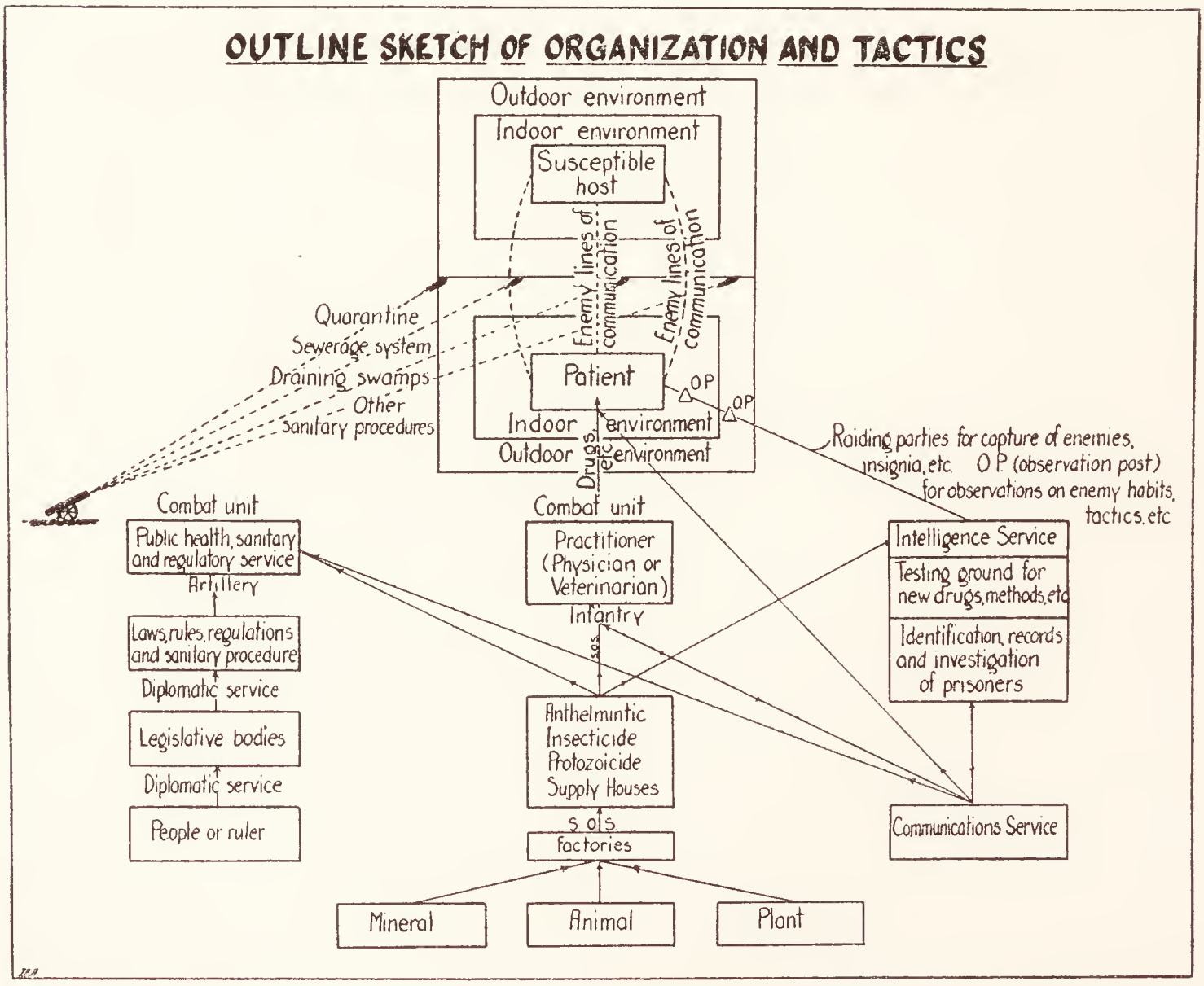
The present writer is attempting to evaluate the situation in our war with the parasites, something which does not seem to have had much attention. In a previous publication entitled "Are we losing the war on livestock parasites?" he attempted such an evaluation and concluded that we were losing the war. That is still the situation, but it is still sound strategy to reconsider the situation, to inspect our preparation, and to study for improvement.

Summarizing our situation in the light of these broad principles of strategy, we may say that while we are prepared for local skirmishes and minor successes, we lack effective leadership, adequate authority, definite purpose, sufficient forces, and suitable weapons for large-scale campaigns against most of our parasite enemies. The only country now carrying out such large-scale campaigns with a plan of action of a continuous sort, is the U. S. S. R. where centralized governmental authority makes it possible. It should be noted that the centralized power of Italy, Germany and Turkey has not given a similar result, that the first large-scale campaign of this sort, that against cattle ticks, was carried out in the democratic United States, and that a similar campaign is being carried out in the democratic Union of South Africa. Obviously we need no dictator to enable us to attack a parasite enemy effectively, but we need in all countries an aroused interest, active support, government by experts, and intelligent legislation against other enemies as we have had these things, to some extent, against the cattle tick in the United States.

Tactics

It has been noted that attacks are by fire and movement, and that while we excel in fire, our parasite enemies excel in move-

ment. We have already listed the weapons at our disposal, and the ways in which our enemies move. The writer has pointed out in previous publications the ways in which man's modern transportation simultaneously serves to transport our parasite enemies. Parasites move rapidly in occupied host terrain from state to state and from one country to another by train, auto, truck, ship and even airplane. An increasing density of human population has led inevitably to more livestock, and thus to a greater exposure of our allies to enemy attack through denser stocking of smaller pastures, simultaneously shortening the parasite lines of communication, enabling them to move on the inner lines so favorable to strategy and tactics, and increasing their opportunities to attack and their density of deployment. The result is more victories for the enemy and a resultant extension of his front. Taylor



(1931) has pointed out that the number of worm eggs picked up on a pasture increases as the square of the density of stocking; if one animal picks up a given number of eggs on an area, two

animals will pick up four times as many, and three will pick up nine times as many. In other words, the density of enemy deployment on a battle field increases as the square of the number of host animals on the field.

General Procedure of Battle

All combats are the attack on and defense of a position. Parasites hold positions in definitive and intermediate hosts, on pastures, in barns and barn yards, etc. In almost all cases in all stages, and almost all positions held, they have the tremendous advantage of practical invisibility so far as naked eye observation under ordinary conditions is concerned. External parasites are silent except for such as the mosquitoes which hum audibly. The internal parasites are absolutely silent. Consequently their movements are practically always carried out with the profound secrecy that is so valuable in warfare. They also have the advantage of great rapidity of movement by virtue of the fact that a small initial invading force quickly recruits larger forces by breeding. Their recruiting service is marvelously efficient. They must be attacked at their weakest points, but only a strong Intelligence Service can ascertain these points.

Attacks are by *fire* and *movement*. *Fire superiority* is of tremendous importance. If a parasite by virtue of its pathogenic weapons is killing or keeping at a low level of health a human being or one of our allies, a domesticated animal, and we can attain fire superiority with anthelmintics, insecticides or other drugs we can destroy the enemy and gain a victory. But if we have no weapon effective against that enemy unit, the parasite maintains fire superiority and we should avoid battle on that field. The essential attack on that position, that of the parasite in the host, cannot be made, the position is held by the enemy, and the enemy is free to exploit his advantage by disabling or destroying us or our allies. It is impossible in such a case to "shoot the enemy out of his position." If we have suitable weapons and can capture a position of this sort, the enemy usually counter-attacks as soon as the firing is over, infiltrating back into his old position by degrees until he is back in force, unless we cut his lines of communication by artillery attacks. Against this infiltration the host may interpose some resistance in the way of immunity, partial or complete, but as a rule we must turn our artillery and other forces

on the enemy lines of communication and by cutting them prevent the enemy counter-attack and recapture of the position.

For cutting the enemy lines of communication we have two types of artillery which I designate as heavy artillery and light artillery. Heavy artillery is that composed of positive-acting weapons of absolute value; weapons that usually destroy the lines of communication at which they are aimed, wherever and whenever these weapons are employed; these weapons are not without flaws, but are our highly effective artillery. Light artillery is that composed of positive- or negative-acting weapons of relative value; weapons that destroy some of the enemy lines of communication at which they are aimed, but are largely productive of relief to our forces in a defensive operation rather than destructive of enemy forces in an offensive. The weapons already listed in Section I for cutting enemy lines of communication, may be grouped on this basis as follows:

Heavy Artillery

Frequent and thorough removal of feces with shovel, broom and hose

Use of strong (coal-tar) disinfectants on floors, etc.
Use of self-heating or steam-heated manure box
Privies, septic tanks, and sewerage systems
Disinfectants for urine
Wire screen and hardware cloth for urine disposal
Screening and mosquito nets against certain external parasites
Isolation of chickens from turkeys for control of gapeworms in chicks
Meat inspection
Cooking food
Snail destruction by swamp elimination or chemicals
Insect destruction by contact insecticides and stomach poisons
Destruction of certain insect breeding places by draining and safe manure disposal
Tick destruction (for 1-host ticks) by dipping and pasture rotation

These weapons are usually highly effective when properly used. Mislabeled weapons or weapons improperly used are not to be confused with weapons correctly labeled and properly used. Coal-tar disinfectants are destructive to worm eggs when used strong

and hot, even in the presence of more or less organic matter, but many disinfectants are fixed and rendered inert by organic matter. Sewerage systems are highly effective, but Ransom has reported a case in which water for cattle was pumped from a river just below a sewer outlet, the use of this water resulting in many cases of bovine cysticercosis; naturally, it does little good to cut the enemy lines of communication and then painstakingly restore the severed lines. Meat inspection is one of our most effective weapons, but only when it is competent inspection by qualified persons.

Light Artillery

All the other weapons listed in Section I for cutting lines of communication may be regarded as light artillery, valuable but not of the positive and absolute value of the heavy artillery.

System of Tactical Instruction

Constant training in warfare is essential for victory. Normal formations and rules must be established, but the officers and soldiers must be able to make adaptations to fit actual situations. No two fields of action, whether host or farm, are alike, and no two parasite problems quite identical in solution. There may be several correct solutions leading to victory; there are usually many possible incorrect solutions leading to defeat. The long battle against yellow fever before it was learned that the enemy used mosquito transport along his lines of communication and in his attack, is a good example of an incorrect solution. Disinfectants for clothing, fomites, etc., were used, and many similar procedures, but all was misdirected energy and effort and wasted time and money. In this case the incorrect solution was the common result in the way of a decision made before the Intelligence Service has obtained the necessary information concerning the enemy.

Military Principles in Parasite Campaigns

In planning a campaign against a parasite force, consider the following points:

1. Identity of enemy forces.

2. Strength of enemy forces. Extent of territory held geographically.

3. What position does enemy hold? In primary hosts? In secondary hosts? On pastures? In stables and barns?

4. What forces have we available? Diplomatic? Combat? S. O. S.? Intelligence? Communications?

5. What weapons are available for attack on enemy in host terrain? This host terrain is a position to be captured if suitable weapons are available.

How can we cut off enemy reserve forces on pastures, etc.? (As by removal of combat to area unoccupied by enemy reserves. By starving out the enemy by removing food supply and cutting line of communication to host as food supply.)

How can we cut enemy lines of communication? Check all artillery available. How can we capture pasture positions? Barn and stable positions?

Consider terrain. Note drainage, shade, water supplies, etc.

Consider time of year, weather, etc.

6. Consider our available effectives. Use of legislation, quarantine, agricultural habits, available federal, state, county and city forces, extension service, educational forces, and medical combat forces of practitioners.

7. Is an organized campaign possible? On an international, national, state, or local basis?

8. Make plans and decisions. Start a war or a battle when victory is a probability. Retreat if defeat is probable (i.e., kill off infested animals and abandon occupied pasture areas to enemy). Never straddle. Foch says: "Of all mistakes, only one is disgraceful: Inaction."

STRATEGIC AND TACTICAL PROBLEMS

In this section a number of problems in the War on Parasites are proposed and discussed. In some cases the decision arrived at is that no effective campaign is possible under present conditions, and that no campaign should be undertaken until we see the possibility of winning the campaign. In some cases a campaign already carried out to a successful conclusion, or obviously headed towards such a conclusion, is analyzed to show the factors present in such a campaign. In other cases campaigns are planned along the lines which would lead to a successful conclusion whenever public sentiment favored a declaration of war and the provision of funds to prosecute the war.

It should be kept in mind that not all of the details are given in these discussions, that not all campaigns are dealt with in equal detail, that the solutions given for strategic and tactical problems are not necessarily the only solutions, but are either the ones preferred by the writer or most useful for illustrating certain points, and that the object of this work is to call attention to a neglected field of economic zoology, the specific study of the subject of control measures as a subject in and of itself, and as something which should not be left on the basis of a subject which will be understood by anyone trained in research.

The General Staff of our army should be recruited from the Intelligence Service, and the writer views with some apprehension the tendency in high places to displace the intelligence officers who hold high places in research organizations and to replace them with officers of the purely administrative type. Undoubtedly the failures of some intelligence officers who have had qualifications for that sort of work only, when these officers have been transferred to administrative positions, have contributed to this swing in favor of purely administrative officers unfamiliar with the work of the Intelligence Service or without high standing in that service. Better training of these intelligence officers in the work of control, thereby training them for the work of the General Staff, may help to prevent in the future the closing of high positions to research workers because of the failure of some of them when confronted with the business of spending public or private funds on control measures.

The same principles that apply in large-scale campaigns apply also in local battles. The practitioner must observe sound princi-

ples in treatment, and has not fulfilled his obligations to his client until he has carried out or indicated the prophylaxis necessary or advisable to prevent further trouble.

In previous papers, the writer has stated the factors in anthelmintic medication as follows: (1) Practitioner; (2) patient; (3) parasite; (4) parasiticide; (5) purgative; (6) prophylaxis. These might be translated in military terms as follows:

1. The officer in the War on Parasites must be a competent officer with a sound knowledge of the host terrain on which the action against the enemy must be carried out; must be acquainted with the enemy forces, and especially with their location, tactics and strategy; must be familiar with the weapons which he is to employ in combat; must be familiar with the auxiliary weapons of purgation; and must be familiar with the weapons, such as sanitation, with which enemy lines of communication must be cut to prevent further invasions of host terrain by the enemy. As a competent officer he must necessarily be a person of sound judgment, able to apply the general rules of his profession to the special case of any patient brought to his attention.

2. The host terrain must be critically inspected to ascertain what weapons may be used with safety to that terrain. An error of judgment in this connection may lose an engagement or result in losses greater than the gains made.

3. The enemy must be definitely identified, its location and lines of communications known, and its vulnerability to various weapons considered.

4. The infantry weapons for direct attack on an enemy must be given careful consideration as regards their destructive effect on the enemy and also on the host terrain, as regards the volume, accuracy and distribution of fire, and as regards the advisability of simultaneous or successive attacks.

5. The auxiliary weapons of purgation must be considered with reference to their known coordination with the primary weapons, as regards volume, accuracy and distribution, and as regards the methods and timing of the attack with these weapons, some of them being more effective when used simultaneously with the principal attack, and some more effective when sent over the top as a mopping-up party following the main attack.

6. The known artillery weapons available to us and of value in cutting many or few enemy lines of communication, must be considered, and a selection made of those which will best protect the host terrain from invasion or at least from massive and disastrous attacks.

A Military History of the American War Against Cattle Fever Ticks and Piroplasms

The story of the war carried on by the people of the United States against the Cattle Fever Tick and the Piroplasm of southern cattle fever is an epic that deserves to rank with the histories of mankind's greatest wars from Homer's Iliad to the story of the World War. The war against the Tick-Piroplasm forces constitutes a model for warfare against parasites. No other war against parasites has ever been carried out on so large a scale and with such decisive results. All the elements of grand strategy, the employment of diplomatic measures and military forces with a broad perspective and a far-sighted outlook on the future, are present in this war. The accomplishments of the Intelligence Service include some of the most brilliant of the classics of science. A variegated set of tactics has been employed, and an analysis of these tactics is of value to all officers engaged in warfare on parasites of any sort in any part of the world.

Work of the Intelligence Service

The Cattle Fever Tick was first definitely identified in 1821 as a new enemy by Say, who associated it with the enemy forces assigned at that time to the genus *Ixodes,* and called it *Ixodes annulatus.* Say was an intelligence officer who was at one time connected with the University of Pennsylvania. In 1869, C. V. Riley, an intelligence officer who was at one time state entomologist of Missouri and later chief of the federal Division of Entomology, identified this tick as *Ixodes bovis,* an identification which could not stand under the rules governing the Intelligence Service, since the oldest available name must stand. In 1891, Cooper Curtice, an intelligence officer in the zoological unit of the federal Bureau of Animal Industry, proposed to designate this tick enemy as forming a new major group, *Boophilus,* and called it *Boophilus bovis* (Riley) Curtice. Since *bovis* is antedated by *annulatus,* Stiles and Hassall, intelligence officers of the zoological unit of the Bureau of Animal Industry, corrected the name of this enemy unit to *Boophilus annulatus* in 1901.

In 1891 and 1892, Curtice reported the results of a reconnaissance intended to ascertain the habits of the tick enemy. He dis-

covered that the Cattle Fever Tick invades host territory, the bodies of cattle, at a time when the tick is a minute 6-legged larva, changes to the uniform of the 8-legged nymph without leaving the host terrain, and later changes to the uniform of the adult male and female tick without leaving the host terrain. This finding identified the Cattle Fever Tick as a one-host tick, a fact of great importance in connection with strategic and tactical measures. The female tick becomes engorged with the blood of our ally, the cow, and then moves to the ground as a terrain of action, and deposits up to 5,000 eggs. From these eggs hatch the seed ticks or 6-legged larvae which for a time constitute the reserves provided for the campaign of the following season.

When called to action, the seed ticks are the assault troops of the enemy forces. The small, hardy warriors can survive without rations for 6 or 7 months under favorable conditions while waiting for an opportunity to attack. Their strategy involves great quiet and secrecy, as do the strategy and tactics of all parasites. When the seed ticks hatch from the eggs on the ground, they crawl actively about on the ground and then swarm up the grass, shrubs and fence posts, occupying the new positions in force, and lying in ambush awaiting unsuspecting cattle. When cattle approach, the ticks stand to amid great excitement and activity, but quite noiselessly, and on establishing contact they attack the cattle and swarm over them with great promptness. On arriving on the host terrain they dig in, and through successive molts they hold their positions in force unless attacked by man. During this time they live off the captured host, bleeding their victims and drinking the blood. Finally the fully engorged female ticks withdraw from the captured host territory to the ground, and lay their eggs.

The Cattle Fever Ticks held the southern United States under their undisputed domination. Over the same area the southern cattle fever destroyed cattle. Every year the northward movement of southern cattle was followed by outbreaks of southern cattle fever in northern cattle. From various coincidences many southern cattlemen came to suspect an alliance between the ticks and the fever. This suspicion received little support among the intelligence officers of our forces, since no alliance of this sort had ever been known. However, Cooper Curtice, the officer who had made the reconnaissance on the ticks, urged on his C. O.,

Daniel E. Salmon, Chief of the Federal Bureau of Animal Industry, the advisability of having the Intelligence Service investigate this possibility. There is a story to the effect that a stockman named Smith gave Dr. Salmon some excellent reasons for his belief in the possibility of an alliance between the ticks and the fever. Dr. Salmon finally ordered Dr. Fred Kilborne, one of his officers, to make this investigation. In 1889, one lot of northern cattle was placed with North Carolina cattle from which ticks were removed, and a second lot with ticky North Carolina cattle. The first lot remained well, but the second lot contracted southern cattle fever. In 1890, Theobald Smith and Kilborne carried out some experiments, the most conclusive being as follows: Engorged female ticks captured on hosts from the South where the fever was prevalent, were held at the old Bureau of Animal Industry Experiment Station near Bennings, D. C., where they were allowed to lay eggs. When those eggs hatched, the young ticks were allowed to attack northern cattle. These cattle developed the southern cattle fever. In 1889 Dr. Smith made the important discovery that a parasite, which he and Kilborne later called *Pyrosoma bigeminum,* was the enemy that was responsible for cattle tick fever. The results of the investigations of Smith and Kilborne showed that the ticks supplied the transport and the lines of communication for the Piroplasm. The tick collected Piroplasms in blood from invaded host terrain, the Piroplasms went through the tick to its eggs, and from the eggs to the young seed ticks. When the seed ticks invaded new terrain, they made breaches in the outer defenses of the host, and the Piroplasms entered the new host through those breaches. In the blood stream of the new territory, the Piroplasms rapidly increased their forces and took possession. The new territory either surrendered to the invader, who encamped permanently in the captured position, or it was destroyed.

While the Intelligence Service had done splendid work, it had not yet completed its mission. It had ascertained the identity of enemy forces, and the tactics and strategy of the enemies, but it had not yet indicated the weak spots in the enemy lines or developed effective offensive or defensive weapons. At this point N. S. Mayo, an officer who served with distinction at various times with Combat Forces, the Communications Service, the S. O. S., and the Intelligence Service, developed a weapon for the destruction

of the tick. This was the arsenical dip. As first developed it was dangerous both to friend and foe. Sometimes it was too weak and failed to destroy the ticks; sometimes it was too strong and destroyed the ticks and the cattle. To remedy this defect, B. H. Ransom and H. W. Graybill, intelligence officers of the federal Bureau of Animal Industry, made extensive tests of the new weapon, a form of ordnance work that falls to the Intelligence Service in the war on parasites. They ascertained the precise strength of dip that would kill ticks and not injure cows. At the same time, Robert Chapin, another intelligence officer of the B. A. I., devised a test by which this weapon could be examined under field conditions and in the midst of battle, and if found too weak or too strong could promptly be set at the right strength.

With this weapon available, the Intelligence Service pointed out the permanent position of the tick on its preferred host terrain as the weak spot in the enemy position. Cattle could be dipped with the assurance that practically all Cattle Tick forces would be concentrated in the area under fire, and could be destroyed with the arsenical weapon.

Military Aspects of Campaign

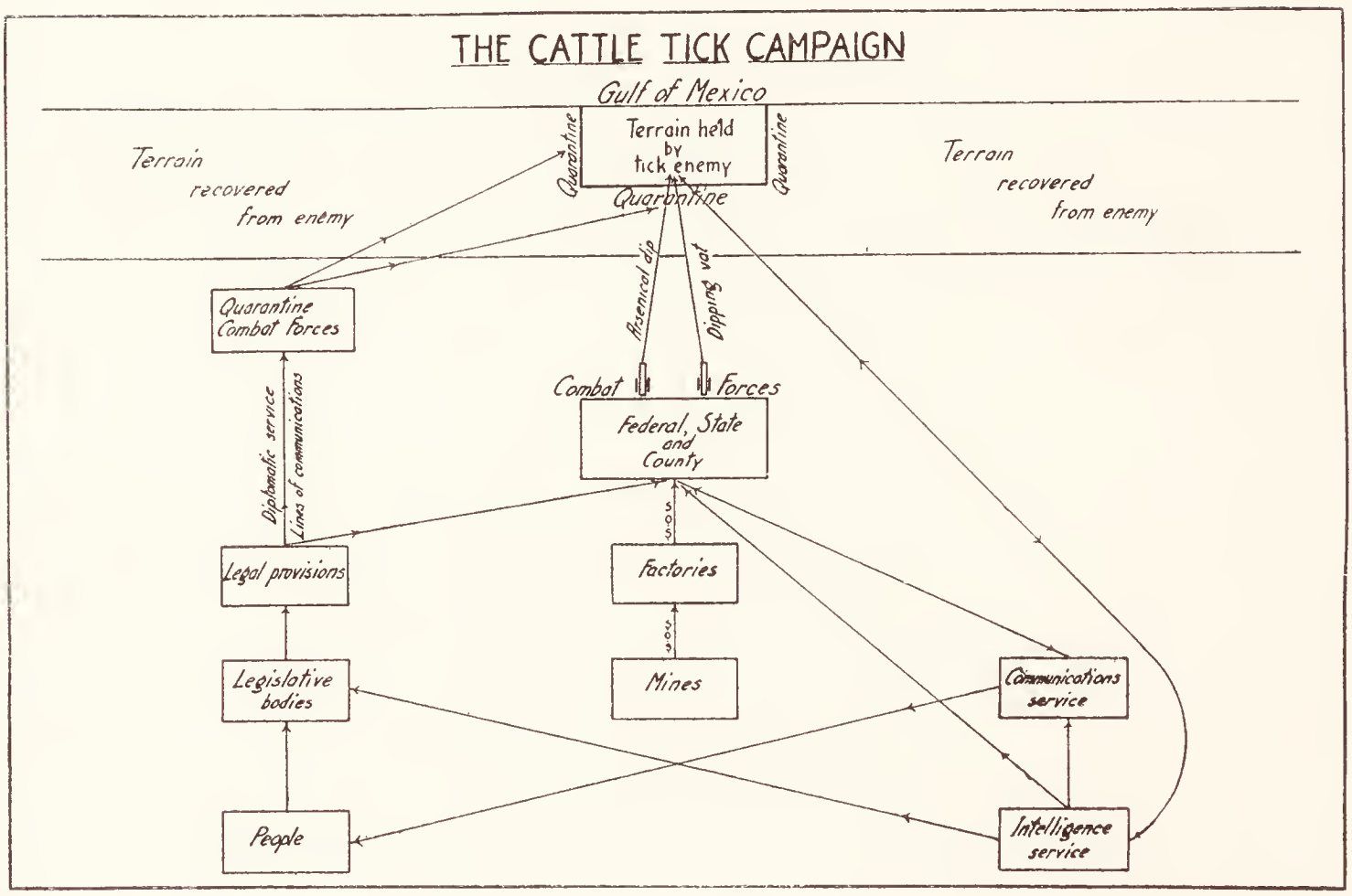
1. *Identity of enemy forces.* The identity of the enemy forces has already been discussed. However, it may be noted that recent investigations of the Intelligence Service have shown that the enemy force identified as *Piroplasma bigeminum* actually included three forces, those of *P. bigeminum,* of *P. argentinum,* and of *Anaplasma marginale,* and that those of *A. marginale* use lines of communication through several species of ticks in addition to *Boophilus annulatus,* and also use insects as lines of communication, and at times use such instruments as hypodermic needles and dehorning saws, in transport from invaded territory to new territory. However, we are dealing now only with the Cattle Fever Tick and the Piroplasms.

2. *Strength of enemy forces.* The enemy forces held the southern United States in undisturbed possession, in addition to making summer raids into the North. The northern boundary of the southern territory occupied throughout the year, approximately ascertained in 1885, will be discussed later. Within the area permanently held, cattle were attacked while still calves, and these calves usually surrendered to permanent occupancy by the

forces of the Piroplasms and annual invasion by those of the tick. Cattle coming into this territory from the North were usually attacked and promptly destroyed.

3. *Positions held by the enemy.* The ticks held the host territory and the pastures more or less alternately throughout the year with some overlap in time. The Piroplasms held host territory in cattle and in ticks.

4. *Forces available against enemy.* For a while there was only skirmishing against the tick forces. Cooper Curtice led the fight in a campaign to drive the tick from North Carolina, using Beau-



mont oil, a weapon which was used for a time before being discarded for the superior arsenical weapon. For this gallant attack Cooper Curtice became affectionately known as "The Father of Tick Eradication," a title earned by this pioneer action at a time when most military observers were convinced that the tick forces could not be defeated.

The Diplomatic Forces have been immensely important in this war. They have constituted the strongest of our forces when they were adequate, and the weakest when they were inadequate. One requirement of sound strategy was complied with in the exist-

ence of a competent commanding officer, the Chief of the Federal Bureau of Animal Industry, with full authority to act along all state lines in keeping enemy forces from invading unoccupied territory, and with delegated authority to command Combat Forces in the various states. The officers serving in this capacity were successively D. E. Salmon, A. D. Melvin, and J. R. Mohler. In 1891, the first of these, D. E. Salmon, drew a quarantine line across the United States along the northern boundary of the territory occupied by the tick, as ascertained in 1885, and issued the orders governing the movement of cattle across this line.

The Federal Combat Forces in the field were ably commanded by Dr. R. P. Steddom from 1906 to 1912, by Dr. R. A. Ramsay from 1912 until his retirement in 1932, and then by Dr. W. M. MacKellar. These forces cooperated with the forces of the State Veterinarians, the two forces in a state sometimes attacking the enemy along the same sector, and sometimes taking separate sectors. On July 1, 1906, congress made available an appropriation of $82,500 for the opening of a real campaign, and, with this, war was declared and the fighting began in earnest.

5. *Weapons available for attack on enemy.* The most powerful weapon available for destroying our enemies was the arsenical dip used against tick enemies on the host terrain. Cattle were driven through wooden or concrete vats filled with this dip, once every 14 days, beginning in March and continuing until November.

As an alternative to dipping, ticks were sometimes attacked on the pasture terrain, being starved to death by cutting their lines of communication between pastures and cattle by a system of pasture rotation. It was ascertained that the seed ticks on pasture, when held there by cutting their lines of transport to cattle, will starve to death in 2 to 8 months, depending on the season of the year.

The diplomatic weapons, as already noted, were immensely important. The federal quarantine forces cut the enemy lines of communication leading into areas from which they had been driven out, or which they had annually invaded. The federal quarantine lines were reinforced by state quarantine lines. Tick eradication laws, providing for compulsory dipping, were passed by the various states. Stock laws requiring the fencing in of livestock were urged on state legislatures as essential preliminaries to a successful cam-

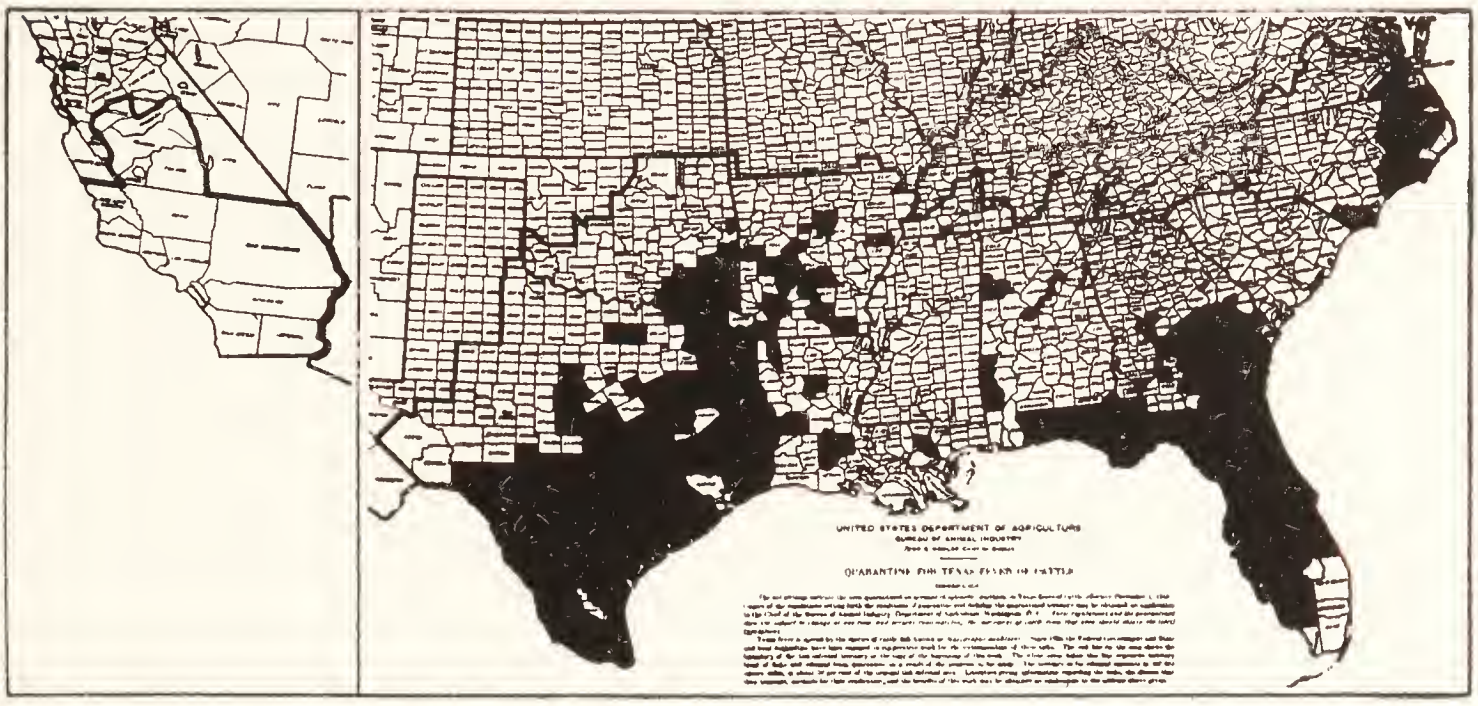
paign, and were occasionally obtained, sometimes after years of diplomatic effort, and sometimes after the ticks had been driven out.

6. *Plan of campaign.* General orders for the campaign were issued from time to time from Washington, but the broad strategy was clear in 1906, and the orders of that date have been in effect ever since. They were substantially as follows:

(1). The Federal Combat Forces would begin operation on the frontier of the enemy's territory, namely, the quarantine line marking the northern limit of year-round occupation by the enemy forces. This line started on the Atlantic coast near the northern border of North Carolina, swung inland a little way, curving northward into Virginia, east to a strip of coast in southern Virginia, then west through southern Virginia into western North Carolina, to the northern border of South Carolina, north in North Carolina and then south to the border of the Carolinas, made a short loop in northern Georgia, extended north across Tennessee into southern Kentucky, back into and across Tennessee in several loops to the Mississippi River at the Tennessee-Arkansas border, and north to Missouri, along the Arkansas-Missouri border, north a short distance into southern Missouri, west on the Arkansas-Missouri border, north near the Missouri-Oklahoma border, west on the Oklahoma-Kansas border for some distance, then southwest across Oklahoma to the Oklahoma-Texas border, south on this border, southwest across Texas to Mexico, next along the United States-Mexico boundary to California, north on the Arizona-California border and a short distance along the California-Nevada border, then in an irregular course west across California to the Pacific coast on the border of Monterey and San Luis Obispo counties (See map).

(2). Preliminary to opening the campaign in any state in the enemy territory, the Diplomatic Forces would take the steps necessary to secure cooperation from allied state forces, providing for quarantines, funds for carrying on the war, stock laws when these could be secured, and similar necessary provisions.

(3). As another preliminary, the Service of Communications would bring the need for and advantage of the war to the attention of the stockman, and endeavor to obtain his cooperation. All possible efforts were to be made to secure enthusiastic support for the war.



Map of the War against the Piroplasms and the Cattle Fever Tick, showing the status of the war in December, 1919. The area bounded by the Atlantic and Pacific Oceans, the Gulf of Mexico, and the heavy black line to the north, is the area held by the enemy at the beginning of the war in 1906. Within this area, the black areas are those still held by the enemy, and the white areas are those taken by us up to December, 1919. In 1933, the enemy held positions only in Texas, Louisiana and Florida.

(4). All enemy forces would be engaged wherever found along their northern front and completely destroyed as rapidly as possible, the attack to maintain a general southerly direction throughout the campaign. Wherever the terrain was favorable for a drive to east or west, leaving a flank protected by a river or a similar favorable topographical feature, the drive would be made to east or west with similar tactics.

(5). Wherever there was a failure on the part of the Diplomatic Forces, and the enemy could not be destroyed at that point, the enemy would be held at that point by quarantine and cut off from reinforcements by drives on his flank and rear. "Exploit success with reserves; break resistance from flank and rear."

(6). Guards would be stationed in all captured territory, and the territory patrolled until there was no further danger of an invasion, when the guards would be released by orders from General Headquarters.

Results. The forces of the federal government and of those states that cooperated loyally deserve more credit than they have ever received. These troops were often on the march at dawn,

moving through the hills of Virginia or across the prairies of Texas to take part in an engagement with the ticks at hundreds of dipping vats. Throughout the day they sent the cattle through the vats, the endless procession of Shorthorns and Herefords, piney woods scrubs and fiery Brahmans. By night they pleaded with recalcitrant legislators in hotel lobbies or argued with hostile cattlemen around the stove in small town grocery stores, or stirred people to action with motion pictures of the war. In some sectors they encountered strong resistance from the tick's allies; many dipping vats were blown up with dynamite and three state officers and one federal officer were killed. In three states armed camps, with machine guns and rifles, were set up around dipping vats to protect them from dynamiters. At times the field Combat Forces fought ticks and the human allies of the ticks for 24 hours a day. The war went on every day of the year, and year after year.

By 1916, ten years after the beginning of the war, the ticks had been driven south and east in Virginia and the Carolinas to a position along the coast. Tennessee, West Virginia and California had been cleared of the enemy. A drive down the eastern slope of the Mississippi River had cleaned much of Mississippi and Alabama, leaving the river to guard our right flank. Along the entire length of the original quarantine line the tick had been driven back to a new line, and 309,131 square miles, or about 43 per cent of the original territory held by the enemy, had been cleared of ticks.

By the end of 1918, the enemy had been driven out of South Carolina and Mississippi. An area of 458,529 square miles, about 63 per cent of the original area held by enemy forces, had been captured, and the road was clear from the original northern line to stretches of the Atlantic and Gulf coasts.

The campaign was not, however, just one uninterrupted victory after another, and in some states the counter attacks of ticks and their human allies won back for the ticks the ground from which our forces had driven them. In 1919, there were only 7 parishes in Louisiana still held by the tick forces. In 1920, the ticks had fought back over the field in Louisiana, recapturing lost positions, and held 21 parishes. In 1921, they held 26 parishes; in 1922, they held 31 parishes; by 1926, the enemy forces held over 40 parishes, and in 1932 were still holding them. Needless to say, the victories of the tick enemies were made possible only by the

defeat of our Diplomatic Forces in their dealings with the human allies of the tick.

While we were losing the campaign in Louisiana, we were driving the tick forces steadily back along other fronts. By 1919 the tick had lost about 70 per cent of the area he once held. For a time the drive slowed up. The enemy positions which were most easily captured had been taken, and the campaign was moving into more difficult terrain, favorable for the defensive needs of the enemy, and unfavorable for our offensive. In 1920 there was only a slight gain, about 1,000 square miles captured. In 1921, the enemy had lost 72 per cent of the territory originally held, but in 1922, as a result of our defeats in Louisiana, the tick had lost only 71 per cent. In 1923 the enemy had recaptured 21 counties in Mississippi, a state from which it had been driven 5 years earlier. In 1924 we retaliated by driving the enemy out of Georgia, but it regained a foothold in South Carolina, a state from which its forces had been expelled in 1918. In 1925 North Carolina was freed of ticks.

From the beginning of the war, the enemy held a small area in the coastal region of Virginia. The terrain was unfavorable to us and favorable to the tick, but the real obstacle to our success lay in the important and often unpredictable field of diplomacy. In 1927 the enemy was driven from this stronghold, and routed out of the area in South Carolina which he had recaptured and held for almost four years. There were now no ticks in the Atlantic coast states except in Florida. Parts of all the Gulf coast states were held by the enemy, as were parts of Oklahoma and Arkansas.

In 1928 the ticks were driven from Oklahoma, and in 1929 from Alabama. In 1930 Mississippi was recaptured by us. In 1928, the quarantine weapon was given a sharper edge. Up to that time tick-infested cattle could be shipped interstate under certain restrictions. After May 1, 1928, all such shipments were forbidden; the tick enemy and the allies of the tick had lost an important line of communication.

By 1932 the campaign had settled down to its final stages. The ticks had been driven out of Arkansas, and had lost 638,103 square miles, or 88 per cent, of the territory originally held. It was now clear that the last battles of the war would be fought in the swamps and palmetto region of Florida, in the bayous and cypress swamps

of Louisiana and east Texas, and in the mesquite thickets of west Texas. At this time (1934) additional men and money are being thrown into the battle in order to bring about a decisive action and end the war. In spite of all the reverses and disappointments, the victorious close of the campaign draws near, and it is now possible to appraise the war as to its costs and benefits.

In 1906 it was estimated that the Cattle Fever Tick and the Piroplasm plundered the people of the United States to the extent of $40,000,000 annually, and lowered the assets of the South annually another $33,000,000. The first federal appropriation for the war, in 1906, was for $82,500; that for 1933-34, $671,089. The total federal expenditures to date are $13,909,304, the total state expenditures to date are $9,703,880, and the total county expenditures are $18,066,520, a grand total of $41,679,520. The total cost of the war will be somewhat larger, apparently by an extra million or two million dollars, but the total cost of the war is less than the loss sustained in one year by the depredations of the enemy before the war began. Every year following the destruction of the last of the enemy forces we shall save the total cost of the war. In addition we shall save many thousands of cattle from suffering and death, a humanitarian achievement of the first magnitude. We shall make possible the development of the livestock industry of the South, and raise the economic level of the entire South and especially of its rural population.

This has been a magnificent war, well officered, well manned, well planned, well fought. Had we been engaged in destroying human foes, either foreigners on our soil or fellow citizens in civil war, our forces would have been loaded with decorations and honors. As it is, no citations, no decorations, and no medals have been awarded. We have destroyed the common enemies of mankind instead of our fellow man, we have left no war debts to plague our children's children, but have arranged to pay to the Republic every year the total cost of the war—and the Republic is indifferent. Some day we shall attain a stage of civilization in which the United States of America will have a government with a somewhat different sense of values. That government will bestow medals for distinguished service on officers who plan sound campaigns against the enemies of mankind, and medals for valor on those who risk their lives and health in the war on disease. And if this prediction fails, and such services continue to go un-

rewarded, there will still be found men—and women—who will respond to Phil Kearney's sentiment: "Go in anywhere, captain. You'll find lovely fighting along the whole line." We shall continue to find adventure and heroism in the eternal war against disease and death.

Campaign Again Yellow Fever and Malaria on the Isthmus of Panama

Historical

Many years ago a French engineer named de Lesseps undertook to build a canal across the Isthmus of Panama. Years afterward a right of way for a canal, some rusty rails in a jungle, and some abandoned machinery reduced to scrap iron and junk constituted the monuments on a battlefield where the Parasites of Man had encountered their ancient enemy, Man, and defeated him utterly. However, it is a characteristic of mankind in general, as it once was of implacable Rome in particular, never to accept defeat as a final word. In the course of time the United States government renewed the attack on the canal, with Colonel Goethals as the engineer officer in command. To open the way for the engineers, Combat Forces from the army engaged in the War on Parasites were thrown into the field under the command of Colonel Gorgas. In a brilliant campaign these Combat Forces defeated the parasites and enabled the engineers to build the canal as a monument on a battlefield where Man had returned from his former defeat and had defeated the Parasites of Man, utterly revenging the hundreds who had fallen victims to these parasites in the first campaign. This second campaign is a model of its kind, and is presented here in detail.

Military Aspects of the Campaign

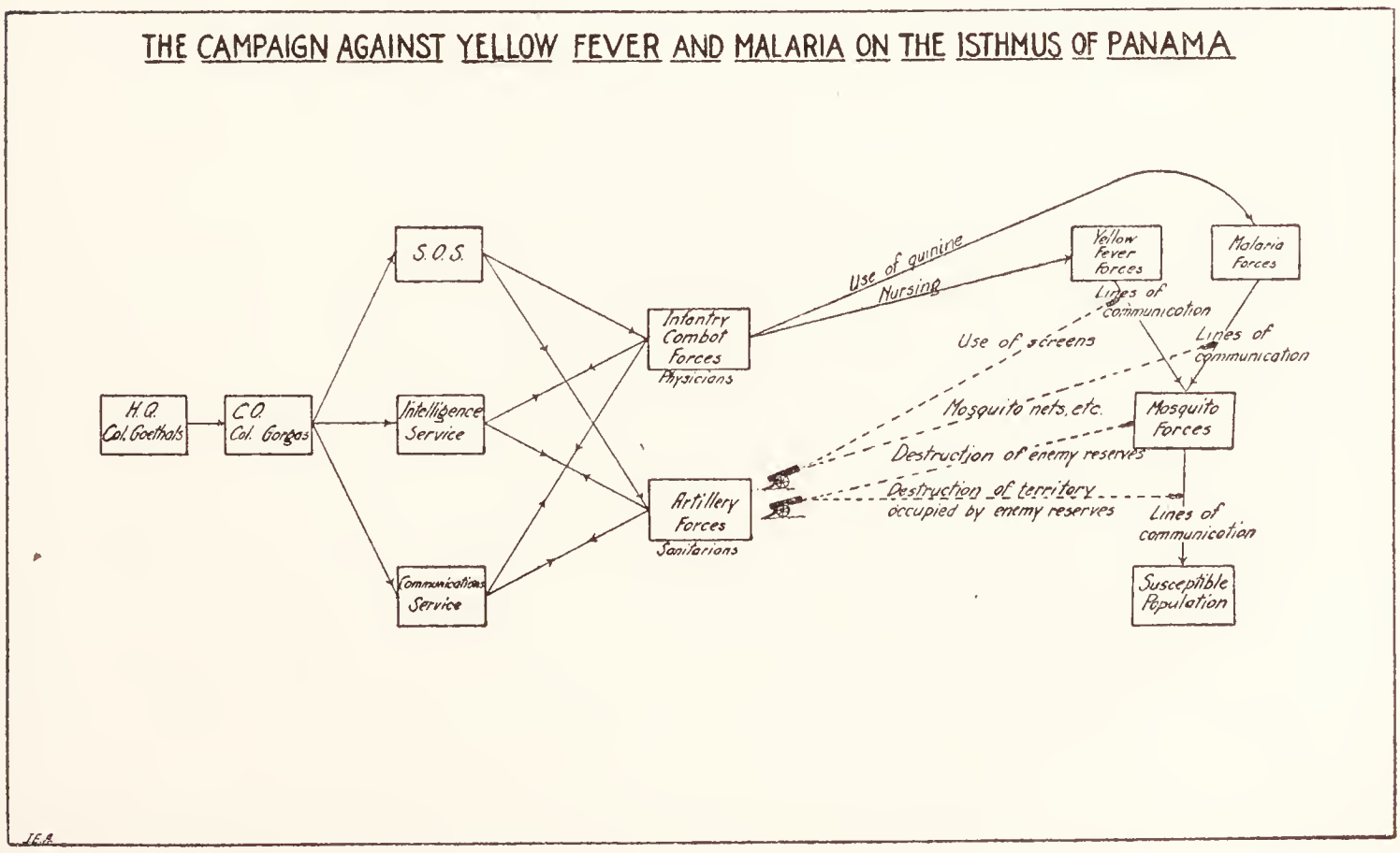
1. *Identity of enemy forces.* The enemy forces present included as major units the organisms of Yellow Fever and Malaria and the Mosquitoes carrying these organisms.

2. *Strength of enemy forces.* These forces held the entire isthmus and the adjacent territory. Part of the native population were veteran campaigners who had survived attacks of Yellow Fever and Malaria and had the advantage of defenses in the way of natural or acquired immunity, or at least of resistance and tolerance. Other natives suffered from more or less disability as a result of enemy attacks, and there was a high mortality annually from these attacks. New-comers were more or less devoid of defense against these enemies, and, unless the enemy forces could be defeated, would be slaughtered as de Lesseps' forces were

slaughtered. De Lesseps' losses were 60.8 killed the first year out of each thousand engaged.

Positions held by enemy. The forces of Yellow Fever held positions in human hosts, and probably in other mammalian hosts, and positions in Mosquito hosts. The forces of Malaria held positions in human hosts and in Mosquito hosts. The Mosquitoes held positions in swamps, favorable collections of water in such pits and holes as were afforded by cisterns, ditches, tin cans, hollows in bamboo posts, and similar positions, these areas being occupied by their larva battalions. They also held positions in houses and other sheltered areas, these positions being occupied by their adult battalions. The larva battalions moved to some extent by water transport, and the adult battalions moved widely and rapidly by air. The Mosquito forces furnished the transport for the forces of Yellow Fever and Malaria, taking reserve forces from occupied host territory during raids on that territory, and delivering these forces on the shores of new host territory during Mosquito raids on these territories. Once landed, the forces of Yellow Fever and Malaria quickly occupied the new terrain and consolidated their position against attack.

4. *Forces available against enemy.* The forces available against these enemies were of a sort meeting the requirements of sound strategy. There was a competent officer, Colonel Goethals, in command, with full authority to issue orders and see that they



were carried out over the Canal Zone and surrounding areas. The medical Combat Forces were adequate and competent, and were directed by Colonel Gorgas, an outstanding medical officer. The S.O.S. was well organized and there were ample supplies of weapons and ammunition. The Intelligence Service of the U. S. Army had ascertained in brilliant fashion the enemy strategy in the use of Mosquito forces to convey the Yellow Fever forces, in the classical exploits of Reed, Carroll, Lazear and Agramonte, following the equally brilliant work of two other intelligence officers, the Englishman Ross and the Italian Grassi, in demonstrating the same strategy in the conveyance of Malaria by Mosquitoes.

5. *Weapons available for attack on enemy.* Where host territory was held by the Yellow Fever organism, no dependable offensive weapons in the form of drugs were available for the destruction of the enemy. Such defensive weapons as nursing, tonic and supporting treatment were brought up, and if the enemy could be held in check until the forces of immunity came into action, victory was assured; in default of this succor, the enemy destroyed the captured terrain and brought death to his victim.

Against the forces of Malaria there was an available and effective weapon, quinine, and this weapon was wielded vigorously by the Combat Forces on the Isthmus.

Against the Mosquito forces there was available a great defensive weapon, screening of houses and cisterns and use of mosquito nets, and several effective offensive weapons, such as draining and filling of marshes and similar breeding places, oiling of breeding places that could not be drained or filled, and destruction of such breeding places as tin cans, the hollows in bamboo structures, etc.

6. *Plan of campaign.* The general orders for the campaign were issued, as already noted, by an officer with entire authority and with adequate forces for an organized campaign. These orders were as follows:

(1) Infantry Combat Forces of physicians to make a frontal attack on the forces of Yellow Fever and Malaria, isolating occupied areas in the form of patients under hospital conditions, keeping up a fire of quinine on the Malaria parasite wherever found, and using screens and mosquito nets to prevent the escape of any enemy forces from these isolated areas by means of Mosquito transport.

(2) Artillery Combat Forces to bring under fire all areas occu-

pied by Mosquito forces as breeding places, destroying these places by drainage, filling or other means wherever possible, destroying the enemy forces with oil or by other means if the occupied area could not be rendered untenable for hostile forces by the other means named, and by means of screens cutting off cisterns from occupation.

(3) The S.O.S., Intelligence Service, Communications Service and other units to cooperate in carrying out the above maneuvers.

7. *Results.* In spite of the fact that the scene of action was laid to a large extent in tropical jungles, where the Combat Forces had to cut their way with machetes to areas occupied by enemy reserves, the campaign was pushed to a complete success. The frontal attacks overwhelmed the enemy forces, and the artillery cut their lines of communication and destroyed their reserves. The destruction of the Mosquito forces closed the air transport lines to the forces of Yellow Fever and Malaria, and the immobilized forces of these latter enemies were readily destroyed. The winning of the war against these enemies made possible the building of the canal.

For their services on the Canal Zone, Colonel Goethals was made a major general and Colonel Gorgas a brigadier general and, a year later, a major general. These were well deserved honors, as were the decorations awarded these officers. It is regrettable that comparable awards will not be made to those who have carried out the campaign against the Piroplasms and Cattle Fever Tick.

Combat Against Sheep Scabies in the United States

Historical

Up to about the beginning of the present century, the Scab Mites were the most vicious and successful of the enemies in the army of the Parasites of Sheep in the United States. In the West the Scab Mites occupied a large part of the host territory. Our Intelligence Service had confirmed the belief held for two thousand years that sulphur was an effective weapon against this enemy, and the Communications Service had brought to the sheep owners the recommendation to attack the Mite army with lime-sulphur dip. However, the sheepmen used this weapon in a casual and ineffective manner and did not follow instructions carefully, mixing lime and sulphur by rule of thumb or by guess instead of accurately, and there was a prolonged controversy in which the potential Combat Forces of the sheepmen bickered with the Intelligence Service and the Communications Service. With our army divided, the Mite army was in a position to invade our territory practically unopposed. Finally, about the beginning of the present century, the matter of weapons was ironed out and a real campaign begun. In this campaign, as we shall see, there were many sound strategic elements that led to sweeping victories, and an unsound element of strategy that has prevented the campaign from resulting in the annihilation of the enemy forces.

Military Aspects of Campaign

1. *Identity of enemy forces.* The enemy forces consisted of three army corps, of which the most important was that of the mite *Psoroptes communis ovis,* and the two less important were those of the mites *Chorioptes ovis* and *Sarcoptes ovis.*

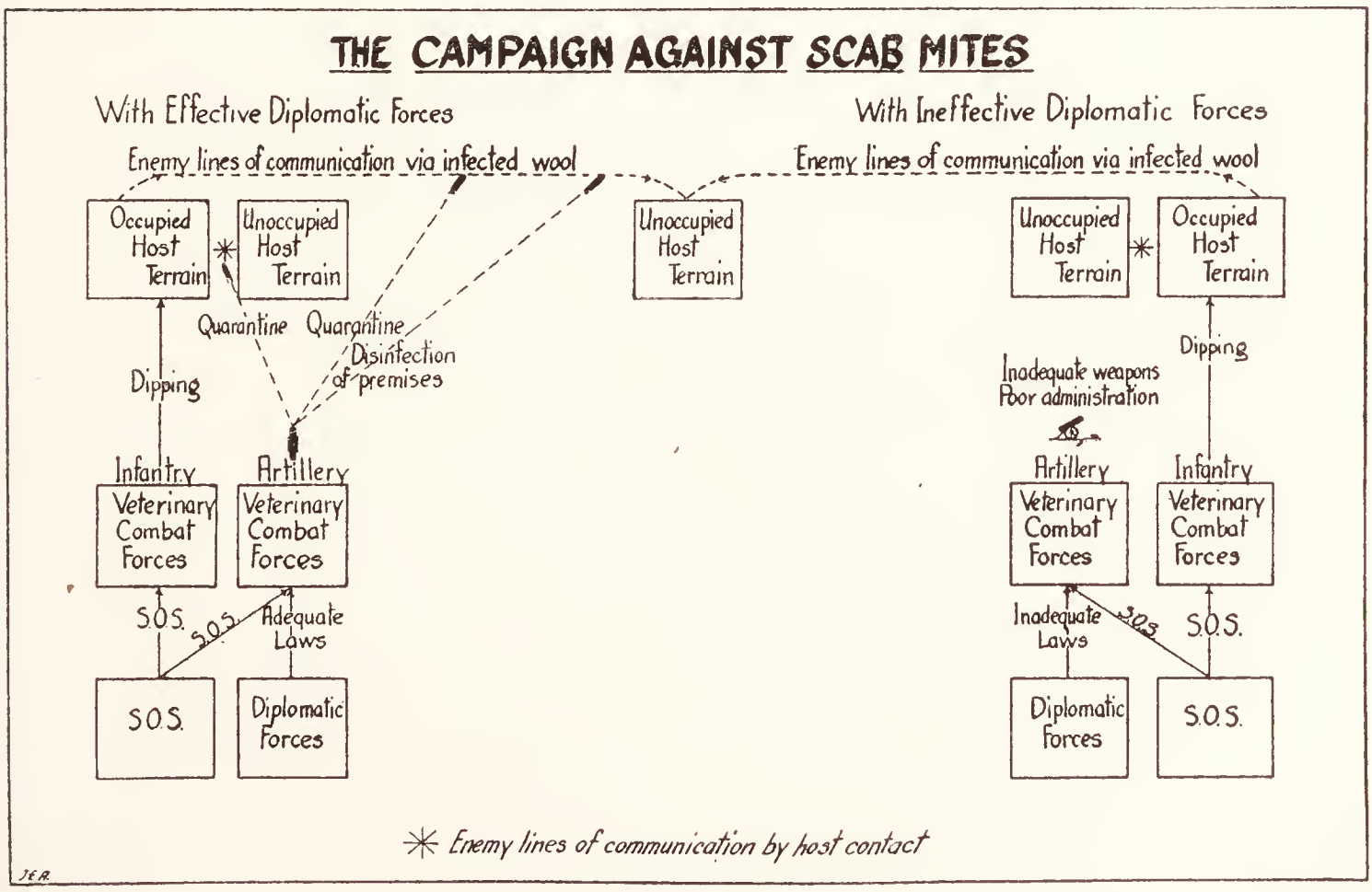
2. *Strength of enemy forces.* These forces held the western and southwestern states in force, with raiding parties ranging most of the other states.

3. *Positions held by enemy.* The psoropts attacked host terrain over almost the entire peripheral extent, digging in, destroying vast quantities of wool, and killing many sheep, either unaided or in conjunction with other enemies. Sarcopts attacked on the head region and choriopts around the lower legs. Their lines of

communication were usually short and direct, by host to host contact, but sometimes longer and less direct by wool from occupied terrain coming in contact with new host terrain.

4. *Forces available against enemy.* When the campaign was finally organized, the diplomatic aspects of our strategy were the features requiring attention first of all. The Federal Bureau of Animal Industry had authority to act in the suppression of animal diseases, and the authority delegated to the Chief of Bureau was vested by him in the Chief of the Quarantine Division (afterwards the Field Inspection Division) as commander of forces for the defeat of the Scab Mites. Under this authority, the powerful weapon of quarantine was put in action to prevent the movement of enemy forces across the state lines from areas occupied by them to unoccupied areas. The movement of sheep from an invaded state to an uninvaded state was either stopped entirely or permitted only when the sheep were dipped at the time of entry. Within the invaded states, the forces of the State Veterinarian, backed by state laws, cooperated with the Federal forces in attacking the enemy.

5. *Weapons available for attack on enemy.* The Diplomatic Forces furnished quarantine measures and legislation drafting into the Combat Forces persons on whose property enemies were found.



The Combat Forces had the weapon of the lime-sulphur dip for the destruction of the enemy forces, together with the newer weapons of the nicotine dip, cresylic acid dips, coal-tar dips, and arsenical dips. The weak spot in our strategy is the fact that under our dual system of government by the federal (national) government and by the state governments, there can be no strict fulfilling of the first principle of strategy laid down by Meyers, i.e., the provision of a commander with authority to assign the missions of all forces engaged. It is possible to have authority vested, so to speak, in a committee, a program which may work, as it did, in effect, at Marathon, but one which is inherently defective and usually a failure. When an enemy is working havoc, as did the Cattle Fever Tick and Piroplasm in the South, or the Scab Mites in the West, the federal forces can obtain adequate cooperation with and support from the states, but where an enemy is not doing a spectacular job of destruction it is difficult to secure adequate cooperation. A weak or political-minded State Veterinarian is a poor ally in the War on Parasites.

6. *Plan of campaign.* The general orders for this campaign, as agreed on by federal and state officers, were substantially as outlined below:

(1) Combat forces to engage the enemy wherever found, destroying his forces with the lime-sulphur dip or nicotine dip.

(2) Lines of communication to be cut by quarantine, and all positions from which the enemy had been routed to be disinfected to destroy any stragglers.

7. *Results.* The results achieved varied rather directly with the diplomatic arrangements and the generalship of the commanding officers in the various states. Where the sheep industry was most important, as it was in the western and southwestern states, sheep were raised primarily for wool. In these states the enemy had wrought the greatest damage in wool destruction, and had invaded the largest amount of territory. As a result the influential stockmen had sought and found sound State Veterinarians and vested in them adequate authority to destroy the enemy forces within their states, and to prevent new invasions from other states. These state officers cooperated effectively with the federal officers, and in a campaign of several years' duration, the enemy was driven from state after state until the important sheep-raising states were freed from enemy forces.

Following these initial successes, the campaign went into the status of guerrilla warfare in the remaining states. In these states the enemy had made fewer invasions and caused less damage, consequently the sheepmen as a whole were willing to take chances on an invasion and unwilling to make war effectively and suffer the hardships of effective quarantine warfare. There was less demand than in the West and Southwest for State Veterinarians of the non-political professional type, and consequently there were more of the political and more or less non-professional type. With less effective officers in command, with a less vigorous war policy, and with a relaxation of effective quarantine, the Combat Forces have dissipated much of their energies in running down small enemy forces here and there and destroying them, without being in a position to exploit these victories by cutting all enemy lines of communication, and annihilating all enemy forces within a state, and holding the captured territory against counter attacks.

The diagram shows on the left the situation in the West where adequate artillery forces backing up the infantry attack have completely annihilated the enemy forces, and on the right the situation over most of the United States outside of the West, where inadequate artillery, represented by a broken cannon, has failed to cut the enemy lines of communication and retreat, and has left the victories of the infantry forces unexploited and allowed the enemy to escape and recover.

In all probability the Scab Mite forces now present in the United States could be annihilated in a vigorous campaign pushed for two or three years at no great expense or hardship. In default of such a campaign, the present form of warfare might continue at greater total cost and inconvenience for many years. It is sounder strategy to push a campaign vigorously with adequate forces, these being available, than to prolong a war by inaction or half-hearted pursuit of the enemy.

Outline for a Campaign Against the Common Sheep Liver Fluke and the Large American Cattle Fluke in the United States

Historical

The distinguished Swedish intelligence officer Linnaeus gave the name *Fasciola hepatica* to the Common Sheep Liver Fluke in 1758, but this fluke had been known long before that date as one of the deadliest of the enemy forces in the army of Parasites of Sheep and is also an enemy of cattle, although cattle withstand its attacks better than do sheep. In any one of various countries throughout the world the attacks of this enemy would destroy many thousands of sheep each year, with losses running into millions of dollars.

In 1883, the English officer Thomas, spying on their movements, discovered that it was essential to the enemy strategy to utilize certain snails as lines of communication from invaded definitive host areas to uninvaded definitive host areas. The adult forces of the enemy occupied strongly intrenched and apparently impregnable positions in the liver of the sheep, the older warriors lying in the bile ducts, gall ducts, and gall bladder. The eggs produced by these forces passed to the host intestine and out in the feces onto the pasture. The eggs which reached water hatched, and the young fluke or miracidium, swimming by means of cilia, moved actively about in search of certain amphibious snails (snails with a right-handed twist to the shell, i.e., with the shell opening facing the observer at the observer's right when the spire of the shell was held upward). On finding such a snail the miracidium attacked it, entered the liver, grew and underwent an asexual multiplication, so that there emerged from the snail a host of enemies for every miracidium that had invaded the snail host terrain. These enemies were now in the uniform of cercariae, and each was provided with a tail. For an hour or so they swam about with a lashing movement forming figures of 8, and then rolled into a ball or cyst surrounded by a defensive armature, either attaching at this time to vegetation or other objects, or floating on the water. In this form they could survive long periods of drying, and when-

ever swallowed by sheep would get to the liver of the sheep and plunder the new host terrain, sometimes destroying it completely and bringing death to the sheep.

For a long time it was supposed that the enemy advanced from the intestine to the liver by way of the gall duct. In 1914, a Russian, Sinitsin, showed that the enemy attacked the intestinal wall, penetrated its defenses to the abdominal cavity, swarmed about in that cavity until they reached the liver, attacked its capsule, took possession of the liver, and settled down in the trenches of the bile ducts and gall ducts.

As early as 1884 the Italians Grassi and Calandruccio began the task of developing a weapon for the destruction of this enemy. In spite of the apparent difficulties in bringing into line of fire an enemy entrenched in the liver, they were successful in finding a weapon in the form of oleoresin of male fern. For many years their findings were ignored, and their weapon left unused. In 1911 the Frenchmen Railliet, Henry and Moussu retested this weapon and found it effective. Soon afterward the Hungarian Marek found that kamala also was an effective remedy. In 1921 Hall proposed carbon tetrachloride as a weapon for the destruction of hookworms, and in connection with its effect on the liver suggested that it might be worth testing against liver flukes. Montgomerie tested it and found it very effective against enemy forces in sheep. It proved somewhat dangerous for cattle, but recently Skrjabin and Schulz reported that after tests of various weapons it has been selected for use against flukes in both sheep and cattle in the campaign of the U. S. S. R. against liver flukes.

The utilization of snails along the fluke lines of communication suggests at once the possibility of cutting these lines of communication by an attack on snails. Asa Chandler reported that copper sulphate was an effective weapon against snails, this chemical being effective in very weak dilutions. Various workers throughout the world have found this weapon satisfactory in campaigns of limited extent under field conditions.

In the United States the federal government opened a statewide campaign in California in 1929. A federal officer, Dr. Robert Jay, was detailed to California to cooperate with the State Veterinarian, the state department of agriculture, the state experiment station, the extension service, and the California Wool Growers' Association. In a campaign lasting three years the fluke was

driven out of practically all the sheep areas. A new campaign was started in Washington and Oregon with Dr. Jay as the federal officer, and another campaign in Utah and Idaho with Dr. Swanson as the federal officer. The campaigns in the United States have been primarily raids on the enemy under the direction of intelligence officers for the purpose of developing adequate weapons, ascertaining the range, destructiveness and limitations of these weapons, and developing tactics and strategy for use whenever an adequate supply of men and money and the provision of officers with adequate authority make it possible to give battle over a wide front with the prospect of victory which alone would warrant giving battle.

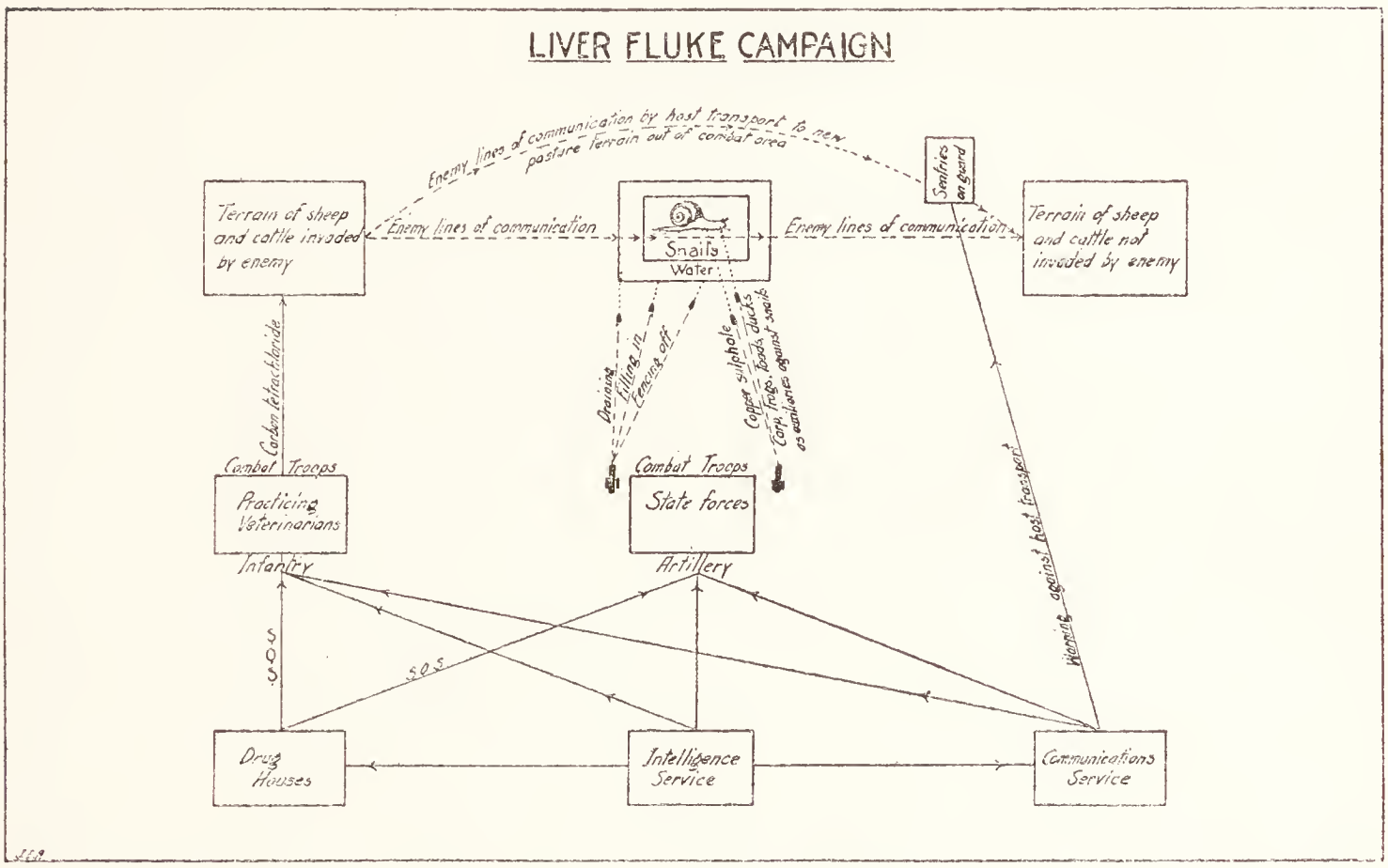
The Large American Cattle Fluke was first found, oddly enough, in an American elk in Italy by the Italian intelligence officer Bassi. He called it *Distomum magnum,* a name later corrected to *Fasciola magna.* The adult forces of the enemy live in the liver of cattle or of deer and other wild ruminants, and in rare instances in the liver of sheep, excavating dugouts in the liver. The tactics and strategy of this enemy are not well known. Sinitsin found that a snail utilized as a means of transport by the Common Sheep Liver Fluke was also used by the Large American Cattle Fluke; Krull has found other snails used by both flukes. Aside from this, little is known of the enemy habits.

Military Aspects of Campaign

1. *Identity of enemy forces.* The enemy consists, as above noted, of the forces of the Common Sheep Liver Fluke (*Fasciola hepatica*) and the Large American Cattle Fluke (*Fasciola magna*).

2. *Strength of enemy forces.* The Common Sheep Liver Fluke holds areas in Washington, Oregon, California, Arizona, Nevada, Idaho, Montana, Wyoming, Utah, Colorado, New Mexico, Texas, Oklahoma, Louisiana, Arkansas, Alabama, Florida, Michigan and Wisconsin. There are reports from scouting parties to the effect that small enemy forces have been seen in Kansas, Nebraska, Iowa and elsewhere in the Middle West, but it has not been ascertained whether these are minor forces in transit (in feeder stock from areas held by the enemy) or are forces actually in possession of these areas and in a position to utilize them as a base of operations for the invasion of surrounding areas.

The Large American Cattle Fluke holds areas in Texas, Arkansas, Montana, New York, California, Michigan, Wisconsin, Min-



nesota, and Oklahoma, and has been reported from Illinois, Iowa and Kansas with some likelihood that the invasion of host terrain in these cases occurred elsewhere.

3. *Positions held by enemy.* The Intelligence Service, as already noted, has ascertained that the adult forces of the Common Sheep Liver Fluke hold positions in the livers of sheep and cattle; the miracidium forces hold positions in water and constitute the forces which attack snails; other forces (sporocyst, redia and cercaria) occupy the snail host terrain; the cercaria forces, on leaving the snail, move by water transport and then encyst as metacercariae on such objects as vegetation or else float on the water; as metacercariae they enter the host terrain afforded by sheep and cattle when these animals eat vegetation or drink water in which are concealed these invading forces.

The Large American Cattle Fluke holds positions in the liver of cattle, deer, and rarely, sheep, and its larval forces hold positions in water and snails. Swales (1935) finds that enemy forces in cattle are trapped and cannot move out as eggs, but can move as eggs from sheep or deer.

4. *Forces available against the enemy.* For the infantry attack on enemies in host terrain occupied by the adult forces of the enemy, we have available the Combat Forces of the practicing veterinarians. For economic reasons, some stockmen will prefer

(6) Every individual combatant of the forces actually engaged in the field will be assigned to a definite individual zone of action and will be responsible for the success of the action within that zone. Two to four days after an engagement, the C. O. immediately in command will go over the zone of action of each combatant with the combatant or a special detail, and collect 100 snail casualties from each zone. These will be placed in water as collected, and if any are found alive, the immediate area of collection and the surrounding area will again be brought under fire. The county and state commanding officers will check selected areas in a similar way from time to time.

(7) Local officers will report on a special form to the county C. O. weekly, or oftener, the report to supply the following information: Location of engagement, giving name of farm, owner of property, or similar identification; distance and direction from nearest post office or other mapped point; extent of area of engagement; number of units engaged; cost in terms of total cost; cost per hour of unit engaged; duration of engagement; results of snail casualty collection; any information of value as to interesting methods of attack. These reports will be summarized by the county C. O. on a special form and sent to the state C. O. The state C. O. will summarize all county reports, making the summary in triplicate on a special form and supplying one copy to the Federal Intelligence Service and one copy to the Federal Combat Officer in command in that district.

(8) The Combat Forces will campaign against snails only when seasonable conditions make effective warfare possible. Campaigns in the Rocky Mountain states and the North will be undertaken in summer, but not in winter when the snails have dug in out of range of our weapons. Campaigns on the West Coast and in the Southwest will be begun when rains have brought the snails into range of our weapons. Campaigns in the South will be carried out over most of the year, but not during dry seasons when snail forces are out of range.

(9) All officers will advise the employment of practicing veterinarians as combat officers for the destruction of fluke forces in sheep, but will be cautious about recommending the destruction of fluke forces in cattle, and will discourage attempts to destroy enemy forces in milking cattle.

(10) All meat inspection forces, federal, state, county or city,

will be requested to report to designated officers all flukes found in livestock, together with the origin of the animals. This information will aid in discovering the areas occupied by the flukes, and check the efficiency of combat troops in destroying the enemy forces. All reports will be followed back to the field by the appropriate officers through regular channels.

(11) In federal and state forests, the cooperation of Forest Service officers will be essential to a successful campaign. On these forest areas the Civilian Conservation Corps should be utilized as combat troops.

(12) The livestock industry will be cautioned not to bring livestock from areas of combat to neutral areas until such a procedure is recommended by the officers in charge. On neutral areas there will be no snail destruction, and all efforts should be made to permit no enemy stragglers in host terrain to utilize these undestroyed lines of communication.

(13) The C. O. in each county will be responsible for the following detail: Previous to launching an attack in any area, a reconnaissance will be undertaken to ascertain the extent and nature of the terrain occupied by the enemy. In connection with this reconnaissance, at least 100 snails will be taken alive from various positions over each square mile of the area reconnoitered. These snails will be packed in jars with *damp, not wet,* Spanish moss, the tops of the jars to be perforated, and the jars put in a suitable mailing case, packed against breakage, and sent to the Federal Intelligence Service.

(14) The Federal Intelligence Service will examine all snail prisoners sent in as to identity, and will ascertain whether they are harboring enemy forces. Reports will be returned to the General Staff, which will supply the Combat Forces with such information as is of value.

(15) All county C. O.'s will supply themselves with topographical survey maps from the Geological Survey, covering the county area involved in the campaign, and will keep on these maps a detailed record of all enemy positions and all actions carried out. The state C. O. will compile a summary of these county maps on a state map, keeping a record of all activities on this map at headquarters, and once a week will furnish a copy of the map, showing an existing status of the war, to the General Staff, and one to the Federal Combat Officer in command in that district. At the con-

clusion of the campaign in each county, the county C. O. will turn in all his maps to the state C. O., and at the conclusion of the campaign in each state, the state C. O. will turn in all these maps and the state maps to the Federal Intelligence Service.

(16) When local assaults on snail forces are following the course of a stream, the attack will start at the headwater or upper reaches of the stream, and continue down stream.

The foregoing plan of campaign might be modified in various respects, and if begun along these lines might have to be modified to meet unforeseen needs. It is planned to secure the destruction of the enemy, and at the same time to enable the Intelligence Service to learn more about the enemy. Obviously, we might do without much of this additional information, but it should be kept in mind that if we drove both of the Liver Flukes from the United States, we should still have to guard against re-invasion, and that anything we could do to strengthen the arms of our allies elsewhere in their combat with these enemies would be to our advantage.

Should We Declare War on Ox Warbles?

Historical

The Ox Warble Forces are very grave enemies of the livestock industry. They cause damage to the invaded host terrain, the damage to hides of cattle being estimated at $50,000,000 a year, and rob the livestock industry of meat and milk to the extent of additional millions. Packers and tanners are eager for a war on these enemies, and in such a good cause our national impulse is to call for an immediate declaration of war. Before we do this, let us analyze the situation.

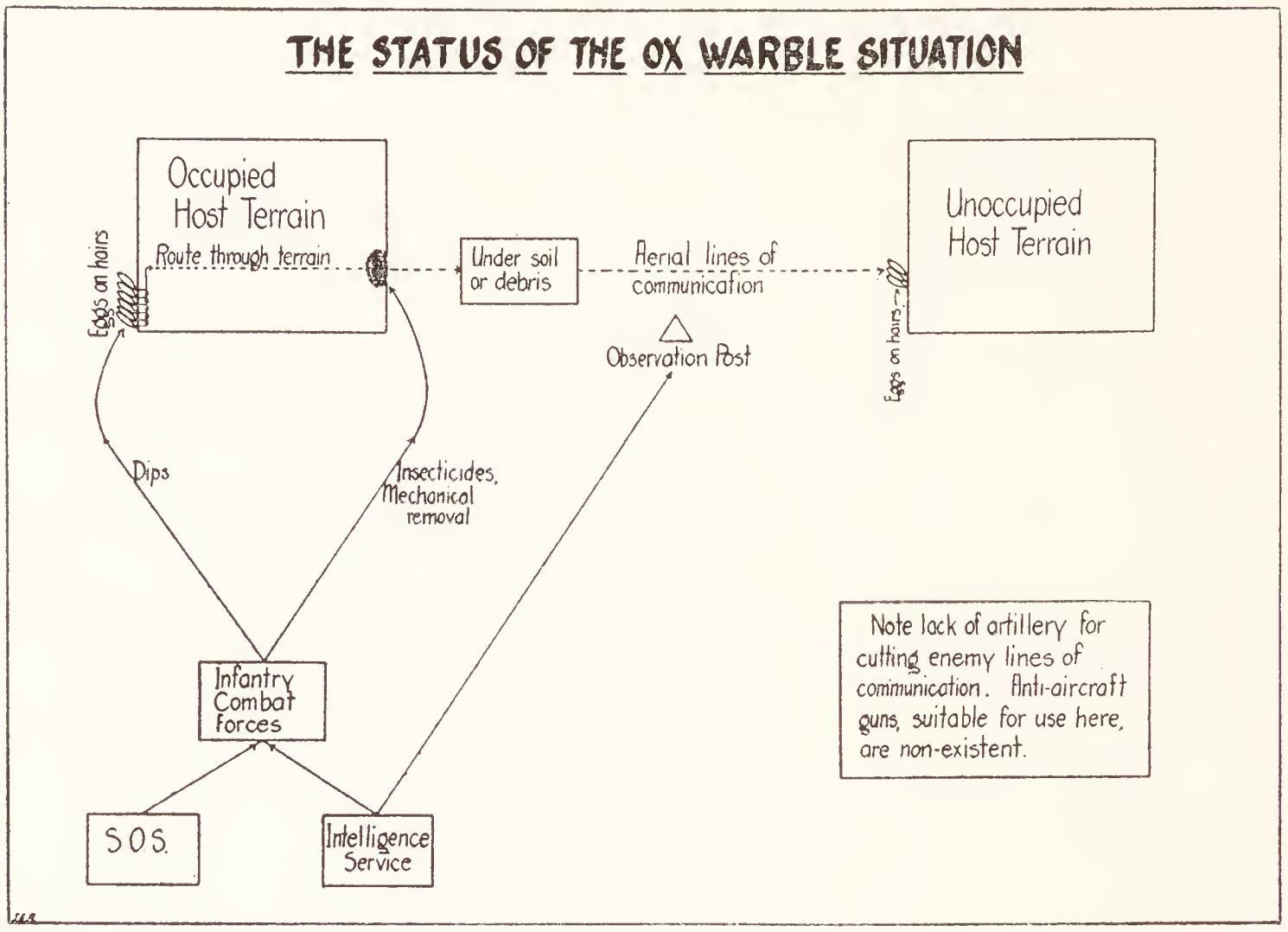
Military Aspects of the Problem

1. *Identity of enemy forces.* The enemy forces include those of *Hypoderma lineatum* and *Hypoderma bovis,* commonly known as Ox Warbles when larvae, or Heel Flies when adult.

2. *Strength of enemy forces. H. lineatum* has long occupied more or less territory in all states in the union, a few places, such as the Red River Valley of the North, being noted for freedom from these enemies. During the past year it was reported that the enemy had obtained a foothold in the Red River Valley. This enemy is widespread over the North Temperate Zone, but does not thrive in the Tropics, and has no foothold in the Southern Hemisphere. It has invaded the Southern Hemisphere repeatedly, but has never been able to maintain itself in that territory.

H. bovis occupies a more northerly range, and is a more recent invader of the United States. It holds territory along the more northern of the western states, and is slowly extending its range of occupied territory southward.

3. *Positions held by enemy.* It has been known for many years that the Ox Warbles held positions in host terrain in burrows under the skin of cattle, the burrows having apertures to the exterior. Over most of the northern United States, the enemy occupies these positions under the skin every winter, cutting open a communication to the exterior usually about November or December. In the spring the enemy forces abandon the dugouts they have occupied while in winter quarters, go over the top through the apertures in the skin, get to the ground, and dig in under debris or in loose soil. In these new quarters the Ox Warbles change from the larval uniforms to the pupal uniforms, and after



a time to the adult uniforms of the Heel Flies. The Heel Flies then sally forth from their terrain in the ground, and take to the air. The adult warriors, male and female, never feed. They mate, and then the females deposit eggs on the hairs on the host terrain, cattle. In a short time the enemy forces push the caps off the shells in which they were concealed, and emerge as Ali Baba's Forty Thieves had planned to emerge from the oil barrels. With no loss of time these forces, the shock troops of the assault, swarm down the hairs and invade the host territory at the bases of the hairs, as Carpenter, Hewitt and Reddin reported. Thanks largely to our able Canadian colleague, the intelligence officer Seymour Hadwen, we know that these forces crawl quietly along under the skin, along the ribs and by other lines of communication, and so make their way to winter quarters under the skin on the back, ready to emerge in the spring and carry the war to new territory.

4. *Forces available against enemy.* The forces available against the Ox Warbles include the Intelligence Services of the federal government and of the states. As Combat Forces there are undoubtedly a number of federal, state and county officers that could

be commissioned for a campaign, but the war would call for a very large enlisted personnel which would have to volunteer without pay or else be paid for the duration of the war; no adequate enlisted personnel of either sort is in sight at present.

5. *Weapons available against enemy.* There are a number of effective weapons available for the destruction of the enemy, once he goes into winter quarters under the backs of cattle and cuts his openings to the exterior. There is the use of a variety of traumatic weapons, including squeezing by hand, or extracting with forceps or a suction pump, followed by destruction by pressure. There is also a variety of poisons that may be used as washes, injections, inunctions or medicated rods, these poisons including cresyls, nicotine, pyrethrum, derris and other things. According to Marion Imes, a weapon that has been found very effective consists of: Derris, 1 ounce; gum arabic, 6 drams; glue, 2 drams; tannic acid powder, 2 drams. These ingredients are made into a stiff paste with a little water, and rods are made from this paste; one of these rods is inserted into each of the enemy burrows with deadly effect on the Warble.

The eggs deposited on the hairs of cattle occupy a position where they are in line of fire and exposed to attack by dips. No satisfactory dip has been developed and found effective for destroying these eggs, but it is probable that one will be developed.

We have no available weapons effective against the forces of the adult Heel Fly, an enemy that moves rapidly and more or less stealthily in its attack on its host terrain, and withdraws from the attack to concealment in places not yet discovered by the Intelligence Service. The defensive weapon of screening serves no purpose in defending terrain on hundreds of thousands of square miles of pasture, forest and mountain area.

Against the concealed pupal forces under ground we have no useful weapon.

Against the concealed larval forces traveling through host terrain to winter quarters we have no weapon.

As regards the use of natural forces against the enemy, two have been investigated.

One is the possibility that a study of such pasture terrains as those in the Red River Valley of the North, and of the Southern Hemisphere, would bring to light the conditions which make it impossible for the Ox Warbles to gain a foothold in these areas,

and that these conditions might be duplicated elsewhere. However, it has seemed probable that the conditions in such areas as the Red River Valley would be in terms of soil and climate, things which could not be altered, and the entomologists of the Intelligence Service state that on investigation they find this to be the case. As regards the Southern Hemisphere, the presumption is that where Ox Warbles invade that area they are met by a reversal of the seasons which defeats them; Warbles ready to go onto summer terrain in the ground find winter conditions prevailing, and those ready to go into winter quarters find summer conditions prevailing. Obviously we cannot reverse the seasons.

Another force which has been suggested is that of a parasite on the Ox Warble. This suggestion meets with the objection that in general parasites cannot afford to kill their hosts, as this would end their food supply. The Intelligence Officers of the Federal Bureau of Entomology state that parasites are unpromising.

6. *Decision as to a campaign.* As already noted, the solution of a tactical problem, and at this time we consider the tactical aspects of this problem, calls for the following estimate of this situation: (a) What is the mission? (b) What are the facilities and favorable conditions? (c) What are the enemies, difficulties or obstacles? (d) How do we accomplish our mission?

Taking up these points:

A. Our mission is to destroy all Ox Warbles in the United States, or to attack locally with limited objectives.

B. The facilities and favorable conditions may be summarized by saying that we have weapons effective against the enemy while he is in winter quarters, and could probably develop weapons effective against the egg on the edge of the host terrain before the invasion.

C. The difficulty which confronts us arises from the fact that to use the effective weapons we have, those for destroying the enemy in his winter quarters, in a nation-wide campaign, calls for an enormous enlisted personnel. To secure this personnel by paying it for the duration of the campaign would cost an enormous sum, and there is no such sum in sight. To secure a volunteer force of the same size actually means that every stockman and farmer must enlist for the duration of the war and serve faithfully without pay in fighting the enemy on the host terrain of his own cattle. To secure such a volunteer army, one of two things must

be done. Every stockman must be shown that his losses in hide damage, meat and milk as a result of enemy forays cost him more than it would cost to serve without pay against the enemy; or else the packer must pay a premium on clean, non-warbly hides that will make it profitable for all stockmen and farmers to serve as unpaid volunteers in this war. At present, neither of these things has been done.

Another difficulty that confronts us is that an effective campaign must be simultaneous on almost all fronts and nation-wide in extent. How far the Heel Fly forces can travel on the wing is not known, but the available evidence is to the effect that they can and do travel at least for miles. We cannot use rivers and hills to guard our flanks in a limited engagement, as such natural obstacles will not save us from reinvasion from occupied territory the following summer. Whether mountain ranges or deserts are adequate protection is not known, but presumably high mountains and extensive deserts are effective. However, such obstacles rarely encircle an area, and the Warbles can circle around the borders of mountains and deserts.

For the most part, all evidence is to the effect that local engagements must take the form of perpetual guerrilla warfare. Whether this warfare is actually profitable is not known. It might prove profitable in some areas and unprofitable in others.

D. So far as one mission is concerned, i. e., so far as annihilation of the enemy forces over the United States is concerned, our estimate of the situation is to the effect that it cannot be accomplished under present conditions. Accepting the sound principle of strategy never to give battle unless with the prospect of victory, we must decline to give battle or wage war on a large scale. As regards local engagements, their value, as judged on costs versus benefits, will probably be variable in different localities.

Recommendations for a declaration of nation-wide war, with a prospect of victory, must await either a quite unforeseen development of weapons or tactics, or the prospect of enlisting an adequate volunteer or paid personnel. The latter is the more probable development, as more wars are won by hard fighting with adequate forces than by new and brilliant strategy and tactics or novel weapons.

Swine Sanitation, a Battle or a Campaign?

Work of the Intelligence Service

In 1915, Stewart, an intelligence officer of the British Army Medical Corps, reported a reconnaisance of the forces of a round-worm enemy of man, which Linnaeus had identified as *Ascaris lumbricoides*. It had been believed that this enemy pursued the very common tactics of advancing from occupied host territory to new territory along the commonly used route of egg production, passage of egg to pasture or soil in feces, embryonation of egg, passage of egg to new host territory by way of the mouth in the swallowing of food, water, etc., in which these egg battalions were concealed, the hatching of the egg in the digestive tract of the host, and the development of the young larva to an adult enemy in the new host terrain. Stewart fed the eggs of *A. lumbricoides* to rats and found that after the eggs hatched in the digestive tract, the young larvae made a long detour via the blood stream route to the liver and lungs, completed a turning movement in the lungs, swinging onto the highway of the air passages, and following the passages to the mouth. Stewart reported his observations, and suggested that larvae in the sputum of rats might get on the food of human beings and so enable these enemy forces to make their way to the intestine of the usual host terrain.

Stewart's report was of major importance, even though his suggestions seemed somewhat improbable and were not confirmed. Reconnaissances were made by Ransom, Ransom and Cram, Ransom and Foster, Yoshida, Koino, and other intelligence officers, with reference to the tactics and strategy of either *A. lumbricoides* or the closely allied enemy, *A. suum,* the latter an important unit in the army of Parasites of Swine. These officers found that Stewart's observations were correct so far as they were first-hand, but that in lieu of the suggestions he had outlined, the actual strategy of the enemy involved retracing the line of march from the mouth to the intestine, his forces encamping in the intestine and developing to adult warriors.

Among the officers who had conducted these reconnaisances, Ransom was distinguished for his ability as a strategist and tactician, as well as for his services as an intelligence officer. At the conclusion of his scouting expedition, he outlined a campaign for

defeating the forces of *Ascaris suum* in their continuous attack on swine. His campaign was based on these facts: Under optimum conditions of temperature and moisture with the most favorable weather and terrain, 10 days is necessary for the egg to become embryonated (Ransom noted that the embryo molted once in the egg; Alicata has found that the egg is not infective until after this molt); it required 10 weeks for the larva to march from the intestine to the blood stream, swim to the liver, land from the portal venous system, fight its way to the hepatic venous system through the defenses of the liver, swim in the hepatic venous system to the right heart and thence in the pulmonary artery to the lungs, land, fight its way through the defences of the lungs, ascend the air passages to the mouth, retrace its line of march from the mouth to the intestine, and develop to an adult enemy in the intestine; and it requires about 4 months for little pigs to develop sufficient age resistance to enable them to expel most of the adult enemies present in the intestinal terrain, and to resist, to a large extent, subsequent attacks.

Military Aspects of Campaign

1. *Identity of enemy forces.* The enemy consists of the forces of *Ascaris suum,* an enemy that cannot be distinguished from the forces of *Ascaris lumbricoides* in any way other than that the former is an effective fighter against swine, capable of invading the swine host terrain along the route given above, of capturing and holding the intestinal position, and of using this terrain as a base from which to invade new territory, whereas the latter is, in the same way, an effective fighter against man, neither being effective in invading and capturing the host territory which is regularly invaded and captured by the other.

2. *Strength of enemy forces.* The swine ascarid holds practically all the United States as captured territory, so far as the existence of swine provides terrain to be captured. The Middle West and the South are most effectively held, the former by virtue of its dense swine population, permitting great density of deployment by ascarids in host and pasture terrain, and the latter by virtue of topographic and climatic conditions favoring rapid development and deployment of enemy forces. The Rocky Mountain states are being invaded with a visibly growing force.

3. *Positions held by enemy.* The enemy holds positions in host terrain, either encamped and entrenched in the intestine or on the

march through the blood stream, liver, lungs, windpipe and esophagus. He also holds positions in pasture and soil terrain, his density of deployment in these positions varying with the density of stocking of swine on these terrains. In small hog lots the ascarid has a high density of deployment, capable of a powerful offensive, whereas on lightly stocked pastures the ascarid has a low density of deployment, incapable of a powerful offensive.

4. *Forces available against the enemy.* For the infantry attack on enemy forces encamped in the intestinal terrain, we have the Combat Forces of the practicing veterinarian.

For the artillery attack on the enemy lines of communication as planned by Ransom, we have the Combat Forces of the farmer and stockman, operating under the direction of the practicing veterinarians, the Service of Communications (especially the Extension Service), and various federal, state and county forces.

5. *Weapons available for the attack on the enemy.* For the infantry attack, there are several effective weapons. One of these is oil of chenopodium, used with an adequate amount of an effective purgative, or followed by the purgative. Another is santonin, used in adequate amounts and followed after a suitable interval by a suitable purgative.

For the artillery attack, Ransom used the most effective of all our artillery weapons, sanitation, the weapon that is useful against the largest number of parasite enemies. For the use of this weapon against the Swine Ascarid, Ransom provided a special set of tactics known as Swine Sanitation, or as the McLean County System of Swine Sanitation, these tactics being based, as noted above, on the known tactics and strategy of the enemy.

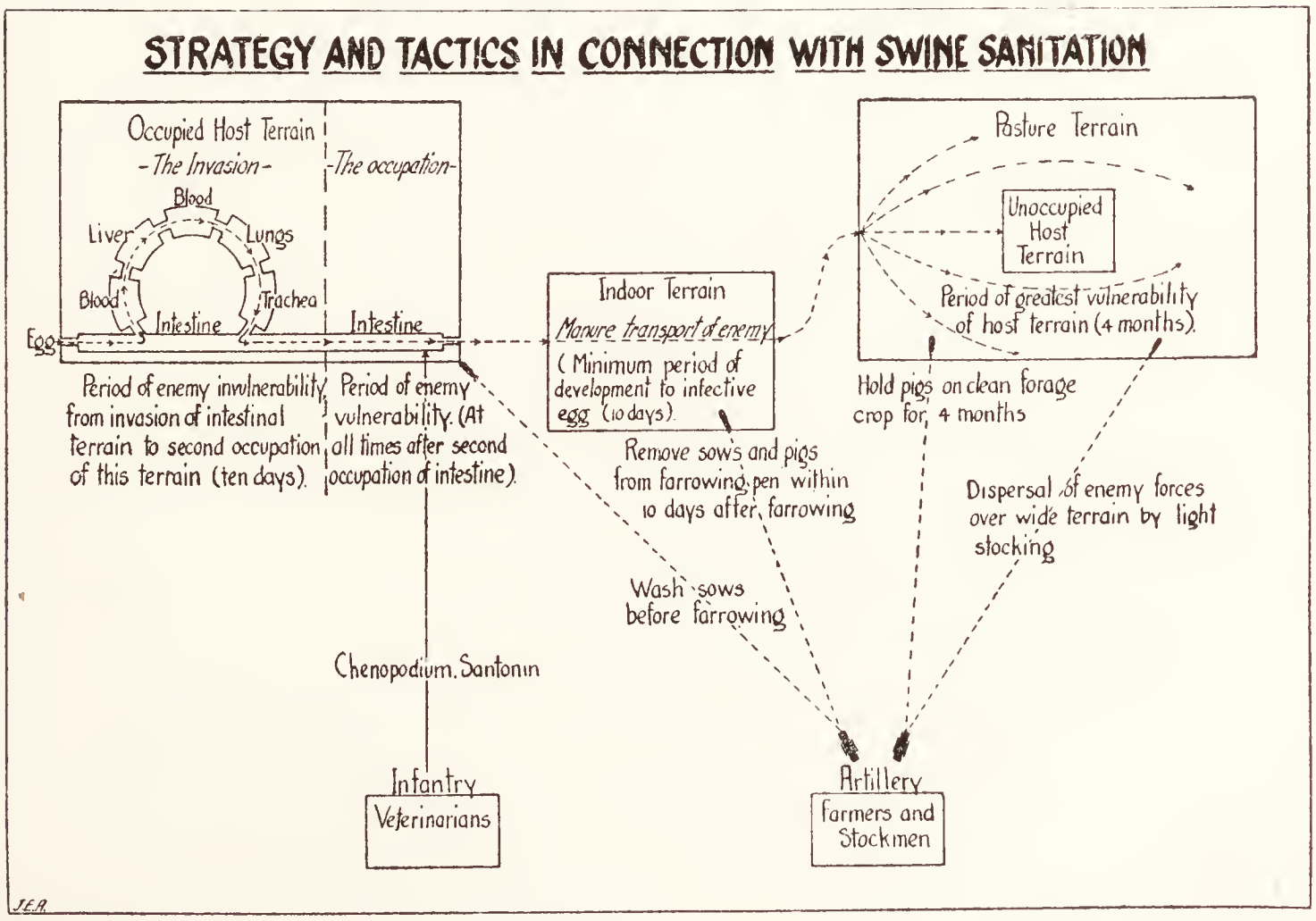
6. *Plan of campaign.* The plan of campaign, as outlined by Ransom, is actually a plan of battle, to be carried out as a local engagement on each individual farm or ranch, coupled with strategic provisions for encouraging farmers and stockmen quite generally to carry out these local engagements over the entire country. This plan of battle, as outlined by Ransom, has a limited objective, i.e., the protection of young pigs against invasion by large enemy forces, thereby protecting the pig against serious injury from ascarids until the pig is 4 months old, after which time the pig has more or less age resistance with which to defend itself from serious injury. As thus conceived, the plan of campaign calls for a continuous form of guerrilla warfare, without

decisive actions looking towards the total destruction of enemy forces.

Ransom's tactics called for this employment of the artillery warfare of sanitation, but he regarded the use of infantry weapons as of no great value. On this latter point the present writer was not in entire accord with his friend and former chief. The present writer regards the more decisive actions as of more value than the less decisive, and regards it as sound tactics here as elsewhere to strike with all available forces, following up every success as vigorously as possible with utter destruction of the enemy as the objective always in mind. The use of the Combat Forces of the practicing veterinarian enables us to destroy the enemy and shut off the supply of enemy reserves constantly recruited from the eggs produced by the entrenched enemy forces. For this reason the general orders given below represent the orders as given by Ransom and as supplemented by the present writer.

The general orders for the campaign against Swine Ascarids are as follows:

(1) Just before farrowing time, the farrowing pen is thoroughly cleaned out and then scrubbed with boiling water, soap and lye to drive out or destroy all enemy reserves present. This applies to farrowing in regions where cold weather, often freezing



weather, prevails at farrowing time, especially the time of the spring farrow in northern states. Fall farrowing in the North, and spring and fall farrowing in the South, may be carried out on the pastures mentioned below.

(2) Before being put in the clean farrowing pen, the pregnant sow is thoroughly scrubbed, special attention being paid to the feet, so that a clean sow is put in a clean pen.

(3) Within 10 days after farrowing (before any ascarid eggs from enemy forces in the sow can reach the infective stage), the sow and little pigs are moved in a wagon or a crate on skids (not driven) from the farrowing pen to a field which has been sown in advance to a suitable forage crop, and on which there have been no pigs since the field was sown.

(4) So far as possible, pigs of about the same ages are kept in the same fields, to prevent larger ones crowding out smaller ones or injuring them.

(5) The pigs are provided with clean safe water and all necessary minerals, and with shade. Shade is best supplied by trees, since trees give the most effective ventilation, the least heating of the shading structure, and the best exposure of soil to alternate sunlight and shade (alternate disinfection and drying, with adequate shade). Since any proper army is meticulously careful of its appearance in peace times, it is not irrelevant to a military line of thought to state that trees furnish the most ornamental shade; many artificial shades are eyesores.

(6) The pigs are kept on these pastures until they are about 4 months old, at which time they should weigh about 100 pounds, and will have developed considerable resistance to invasion by ascarid enemies, and to the weapons of these enemies.

(7) Before sows are bred, enemy forces occupying the intestinal terrain should be brought under fire by the Combat Forces of the practicing veterinarian.

7. *Results of campaign.* The results of the campaign to date are as follows:

(1) The degree of success in attack is proportionate to the care and efficiency with which the tactics laid down here are followed. Failure to follow these orders results in failures to gain the proposed objectives.

(2) When these tactics are followed, the farmer can raise and

market as many pigs from 2 sows as he could from 3 sows under ordinary farm yard conditions.

(3) The pigs raised under these tactics are generally uniform, thrifty and healthy, remarkably free from runts, without "thumps" (verminous pneumonia), and ready for market at the age of 6 months.

(4) In addition to defeating the Swine Ascarid, these tactics are of value in controlling necrobacillosis and other filth-borne diseases, the weapons of sanitation being the weapons of greatest range and destructive power against disease in general, as well as against parasites, of all the weapons we have. It is apparently one of the most effective and promising of all weapons against trichinosis, a matter discussed in the chapter on trichinosis.

(5) The use of this system has been estimated as making a million dollars annually for the farmers of Illinois.

(6) Up to the present time, this campaign has been carried on mostly in the Middle West. It is primarily a defensive offensive, driving out part of the enemy forces over local areas, and holding these areas against counter attacks that might recover the terrain completely. It should be extended widely over the entire country, and pushed with sufficient vigor over the wider front to make it a real offensive. As matters stand, this campaign is fought by volunteers, and volunteers are hard to secure, slow to become efficient troops and prompt to retire at the end of the first enlistment, here as elsewhere.

Trichina, a Deadly and Not Yet Defeated Enemy

Trichina supplies one of the most deadly units in the army of Parasites of Man, and also an important unit in the army of Parasites of Swine. Unlike most units in the armies of parasites, this enemy attacks under the red flag of fever, and medical Combat Forces not infrequently mistake its attack for the attack of bacteria, parasite members of the plant kingdom, which usually fight under this flag. In the last few years, 1929 to 1936, Trichina has been recognized as the attacker in many more assaults than previously. In 1915, Ransom summarized 2,090 necropsies with 45 showing trichina present, or a little over 2 per cent. Post-mortem examinations of persons dying in hospital in recent years in various parts of the United States indicate that possibly 10 per cent of persons in this country have been attacked by this enemy. In New York City there were 80 attacks recognized in the course of 22 months, recently. On this basis we might assume that there are 4,000 to 5,000 cases in the United States annually, which are recognizable to the eye of a fairly well trained combat officer as attacks of Trichina. Probably more than this many cases occur but are not readily recognizable.

Swine are more resistant to attacks by Trichina than are people, but even swine may be attacked and seriously injured, and when so attacked it is unlikely that our combat officers would suspect this enemy as the attacker. Alicata has noted a case in which this enemy was found as the cause of death of a hog attacked under conditions of garbage feeding.

Findings of the Intelligence Service

Many years ago, Peacock in England discovered this enemy lying besieged within the cyst walls thrown up about each individual combatant in the muscles of a human host, and Owen identified it as a new enemy which he called *Trichina spiralis,* a name later changed to *Trichinella spiralis.* Later, an American, Leidy, at that time the only intelligence officer on duty on the parasite front in the United States, noticed something unusual about a piece of ham at a dinner, and slipped the piece of ham into his pocket. An exploration the next day showed the presence of Trichina in the ham. Subsequently a distinguished Intelligence

Service officer, Zenker, found this enemy in a cadaver and obtained evidence that this enemy had killed its host. The enemy sometimes invades other host terrain, notably rats.

The great Leuckart and various other officers ascertained that the enemy tactics and strategy are as follows:

The enemy forces besieged in the positions captured by them in the muscles of a host are transported to a new host terrain when the new host eats the muscles or meat of the previous host. The enemy, in the larval stage when swallowed, leaves his besieged position on reaching the stomach of the new host terrain, moves to the upper part of the small intestine, and entrenches among the villi and folds of the mucosa for the 2 or 3 days necessary to become sexually mature. Mating then occurs and the females dig in until they reach the lymph spaces of the villi. In 4 or 5 days the female begins to send out raiding parties of young larvae, continuing to do this for the 3 months or so that the female lives, each female sending out at least 1,000 larvae. These larvae move rapidly along the lymph channels to the thoracic duct, debouche into the venous system, follow it to the heart, and then scatter over the far-flung highways of the peripheral arterial system. Through the by-paths of the capillaries they march into the areas of the voluntary muscles, invade the connective tissue, and quickly pass on to attack the primary muscle bundles. The captured positions are seriously injured as the enemy grows, and the host throws up its cyst wall about them and besieges these positions, the fibrous walls being completed in about 7 to 9 weeks after the invasion of a new host terrain. As early as 6 months after the invasion, the host may begin to replace the fibres of these walls with lime, and in the course of time attacks the enemy defenses, and finally the enemy itself, by advancing the lime fortifications into the enemy positions. Such an attack ultimately reduces the enemy stronghold and destroys the garrisons. However, the enemy has been said to remain alive in these positions as long as 31 years, although it is usually destroyed sooner if it remains here and does not move on to a new host.

The enemy may move from one rat terrain to another rat terrain or to a swine terrain, and from a swine terrain to another swine terrain or to a human terrain. In man the invasion results first in evidence of gastro-intestinal disturbances as the enemy takes its position in the intestine. There is then evidence of muscular pain

and distress as the enemy forces, multiplied a thousand fold, attack and occupy the muscle sectors, and at this time the host puts up the distress signal of fever, and rushes eosinophiles to its defenses. Finally there is a general edema and anemia, often with pneumonia.

1. *Identity of enemy forces.* As noted, the enemy is known commonly as Trichina, or technically as *Trichinella spiralis.* Its attack is commonly referred to as trichinosis.

2. *Strength of enemy forces.* In 1915, Ransom reported about 1,550 known human cases of trichinosis in the United States, with the death of the host in 240 cases, or about 16 per cent. Since then there have been many additional reports from medical combat officers, from 200 to 300 cases in some years; evidently many more are overlooked. Ransom reported cases from 30 states, but these states represent all major sections of the country and it is doubtful if there are any states where human beings have not suffered from the attacks of this enemy. The medium of enemy transport was raw or imperfectly cooked sausage, ham and pork, lachsschinken, and similar pork products. A microscopic examination of over 8,000,000 swine in the years 1898 to 1906 in the United States, showed live enemies present in 1.41 per cent, and dead or apparently dead enemies in an additional 1.16 per cent.

3. *Positions held by enemy.* This enemy has a most unusual form of tactics and strategy in that it never occupies pasture positions or any terrain other than host terrain. As a larva it invades new host terrain and captures an intestinal sector; as an adult it holds that sector for 3 months or so; its next generation of recruits goes as larvae from the intestinal sector by way of the lymphatic stream and blood stream, captures the muscle sectors, and is then besieged there for years by the host.

4. *Forces available against the enemy.* For the campaign against Trichina we have many potential forces, of which some are actually in the field in force and some only sporadically and half-heartedly engaged. These forces include the Federal Bureau of Animal Industry, various other federal, state, county and city forces, and some less active forces which would be valuable if they could be used more. The forces include units of the Intelligence Service, Combat Forces, Communications Service, and the Diplomatic Service.

5. *Weapons available for the attacks on the enemy.* The avail-

able artillery weapons include: (1) Meat inspection; (2) avoidance of the use of raw or inadequately cooked pork or pork products; (3) the swine sanitation system, or modified swine sanitation system; (4) cooking of garbage; and (5) rat destruction.

It should be said in comment, that there is no microscopic inspection of pork for Trichina in the United States, and never has been except of pork designed for export to certain countries during the years 1898 to 1906. It should also be said that the Federal Bureau of Animal Industry inspects only about 70 per cent of the animals slaughtered for food in abattoirs in the United States, and that outside of the federal inspection there are only a few states, counties and cities that have an adequate meat inspection system. The federal meat inspection system provides for processing pork products customarily eaten without cooking, to the end that any Trichina in the pork in those products may be killed, thus cutting the lines of communication of the enemy between the swine host terrain and the human host terrain. In Germany all pork is microscopically inspected for Trichina. This has undoubtedly reduced the incidence of trichinosis. However, it is very expensive, too slow for the rapid movement of American slaughtering, and has led to a false sense of security in connection with some of its flaws. At one time over 32 per cent of cases of trichinosis in Germany were traced by Stiles to German pork inspected for Trichina and passed as free from traces of enemy activity.

Plan of campaign. Recall that the enemy moves from swine host terrain to human host terrain, from swine host terrain to swine host terrain, at times from rat terrain to swine terrain, and from rat host terrain to rat host terrain. Our indicated line of artillery attack is to shell the enemy lines of communication between rat and rat, rat and swine, swine and swine, and swine and man. The weapons already noted above can be turned on these enemy lines of communication with great destructive effect and with a high degree of protection to the human host terrain.

A possible infantry attack can be dismissed in a few words. We have as yet no drug weapon to supply our medical Combat Forces as a weapon adequately tested and found to be effective. This is true regardless of whether the enemy holds the intestinal sector, marches over the lymph and blood routes, or invades the

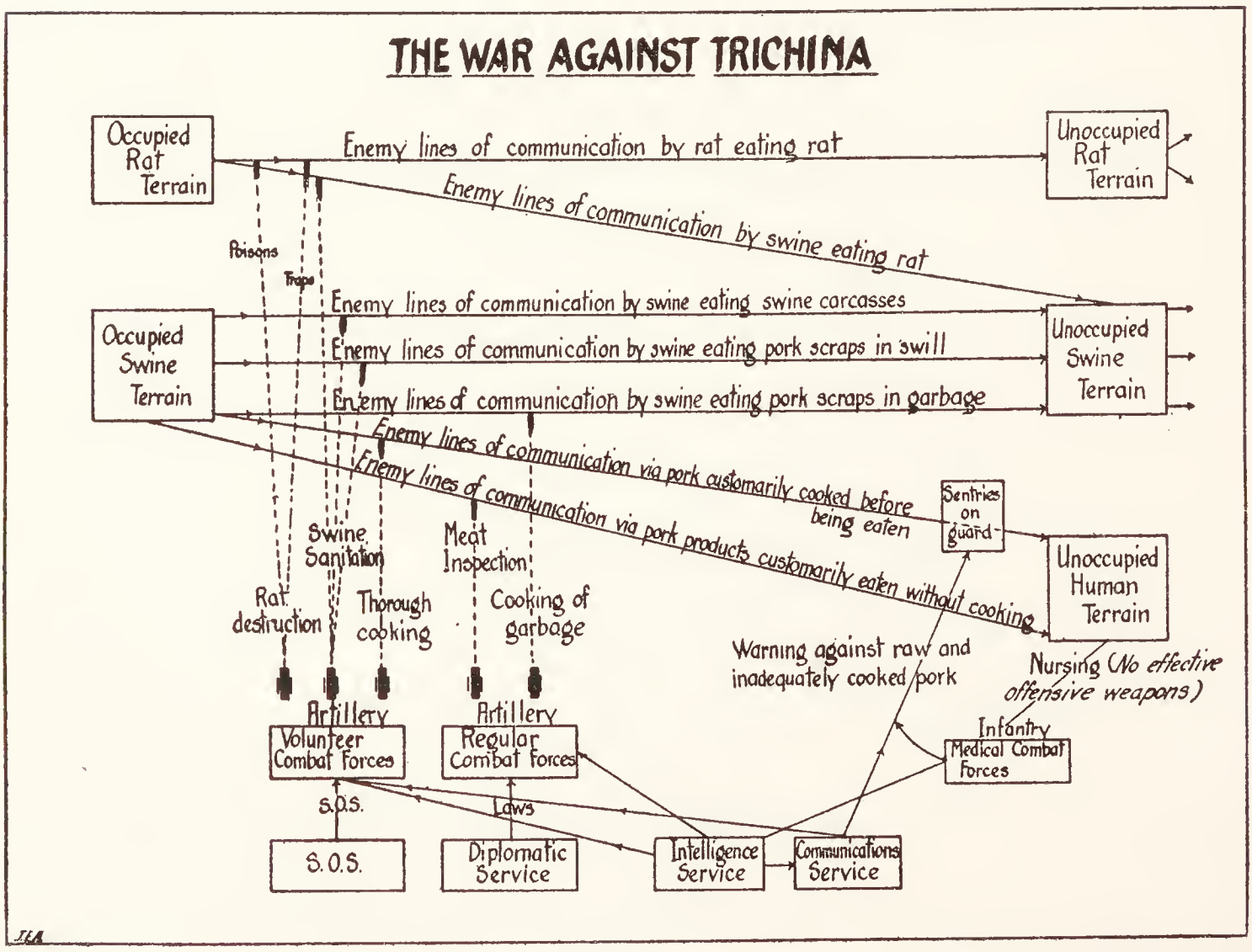
muscle sector and is besieged there. It appears that the forces of immunity, the *vis medicatrix naturae,* are invoked to some extent to protect a host terrain, once invaded, from a subsequent attack or a too deadly result of a subsequent attack. Wantland (1934) reported that calcium lactate and irradiated ergosterol greatly speed calcification and lessen the effects of an attack.

The general orders for a campaign against Trichina at the present time do not contemplate a general offensive. They contemplate a defensive offensive, intended to protect our terrain and that of our allies, swine, against the enemy, so far as possible, but do not contemplate the annihilation of the enemy. Campaigns on a volunteer basis, with inadequate authority or command, can hardly hope to wage war to a finish, as a rule.

Such orders as may be given, and to some extent carried out, are as follows:

(1) The Federal Meat Inspection service will provide that all pork in pork products customarily eaten without cooking, is processed in one of the following ways:

a. The pork will be cooked at such a temperature as will ensure



the death of any Trichina present. The B. A. I. regulations provide for 137° F. (= 58° C.).

b. The pork will be refrigerated at such a temperature and for such a period of time as will insure the death of any Trichina present. The B. A. I. regulations provide for 5° F. for not less than 20 days.

c. The pork will be preserved by the addition of such amounts of salt and retention at such temperatures and for such periods as will insure the death of any Trichina present.

(2) So far as possible, the Diplomatic Service will try to bring under the federal meat inspection service or some equally efficient service, all slaughtering carried out in the United States.

(3) The Intelligence Service and Service of Communications will keep before the public warnings as to the necessity for cooking pork thoroughly, and the necessity, in using pork products customarily eaten without cooking, of seeing that these products bear the stamp of a dependable meat inspection service. Press releases and similar activities of the Service of Communications will be most valuable in the fall at hog-butchering time, as past experience shows that the making and tasting of farm sausage are common sources of trichinosis. These warnings will serve as sentries to the army of consumers who must bring under fire pork that might serve as enemy transport.

(4) The use of the swine sanitation system, as originally proposed or as modified, will be urged on swine raisers generally.

(5) Where hogs are fed on garbage, the garbage will be cooked at a temperature which will destroy any Trichina in pork scraps.

(6) Rat destruction by trapping and poisoning will be carried out whenever possible.

7. *Results of campaign.* So far as a campaign has been carried out, it has served to defeat the enemy at some points, but evidence reported by the Intelligence Service, and already referred to, indicates that we have too little artillery in action to cut all the enemy lines of communication. The situation is as follows:

(a) The federal meat inspection service maintains an effective barrage over the enemy lines of communication via pork products customarily eaten raw. However, there is a too common and quite erroneous belief that pork from houses under B. A. I. inspection

is safe without cooking. Where this belief prevails it leaves one enemy line of communication open; where the sentries of the Service of Communications lay down effective warnings, this line is cut by a public that cooks its pork well. The 30 per cent of animals slaughtered outside of federal inspection, rarely comes under inspection of a sort effective in cutting the enemy lines of communication. Hence the combined barrage of our Meat Inspection Forces and sentry duty of the Service of Communications serve to cut or to hamper some, but not all, of the enemy lines of communication from swine to man.

(b) The Intelligence Service has debated the question as to whether swine are most often invaded by Trichina as a result of eating swine or eating rats. Some years ago the writer pointed out that from the standpoint of tactics this point is academic, since we have a weapon that is effective, regardless of the fact in this case, in cutting the enemy lines of communication to swine. This weapon is the swine sanitation system, original or modified, a highly effective weapon but too little used.

Under a swine sanitation system, pigs are raised on pasture and not in dirty hog lots and pens. On these pastures pigs will have little or no opportunity to eat rats, since rats live around outbuildings and hog lots, where there are shelter and suitable feed, and not on pastures where there is little or no shelter and little feed of the sort rats desire. Furthermore, pigs under the swine sanitation system will have no opportunity to eat other pigs, since farmers intelligent enough and ambitious enough to use the swine sanitation system will have few dead pigs to deal with and will not leave these lying around. Finally, pigs raised under the swine sanitation system will not be fed swill or garbage, and hence will not be exposed to pork scraps containing trichina.

(c) Swill feeding is an accompaniment of the dirty hog lot, and garbage feeding is a special form of swine raising. Garbage feeding furnishes ideal lines of communication for trichina. A study of garbage-fed hogs indicates that trichina may be present in large numbers or completely absent. The absence of an enemy on a splendid road does not mean that the road is unsuitable to the enemy and need not be guarded. It means only that the enemy forces have not yet reached the road. Once they reach it they will use it unless they are driven off it by the employment of suitable forms of warfare. Cooking garbage is an effective weapon

in cutting the wide road of enemy transport from swine to swine afforded by garbage feeding. The diplomatic forces should make the use of this weapon compulsory in the United States as it is in Canada.

Fighting Haemonchus

It has been noted as a principle of military science that strategy cannot make use of indecisive battles. Like principles in general, this principle is qualified by other principles. Another principle is that battles are the attack on and the defense of a position, and that the continual surrender of positions must end in defeat. So far as decisive actions, ending in the destruction of the enemy forces are concerned, it was said of General Sherman that he never won a battle; but he never lost a campaign. In the long march from Chattanooga, Tennessee, to Atlanta and Savannah, Georgia, and north to Goldsboro, North Carolina, he flanked General Johnston and other generals out of one position after another, never decisively defeating them or cutting off their retreat, and refusing the decisive victory that was in his grasp when Mower rolled up the Confederate flank at Bentonville, North Carolina. Nevertheless, the strategic value of that march was greater than would have been a decisive victory with the destruction of the Confederate army.

We have a somewhat similar position as regards our campaign against the Common Sheep Stomach Worm. We can drive it from one position after another and if it retakes a position we in turn can recapture the position. We can slaughter 99 per cent of the enemy forces in one engagement, even though we cannot, at present, annihilate this enemy in battle. However, we can win our campaigns and save our flocks from destruction.

Findings of the Intelligence Service

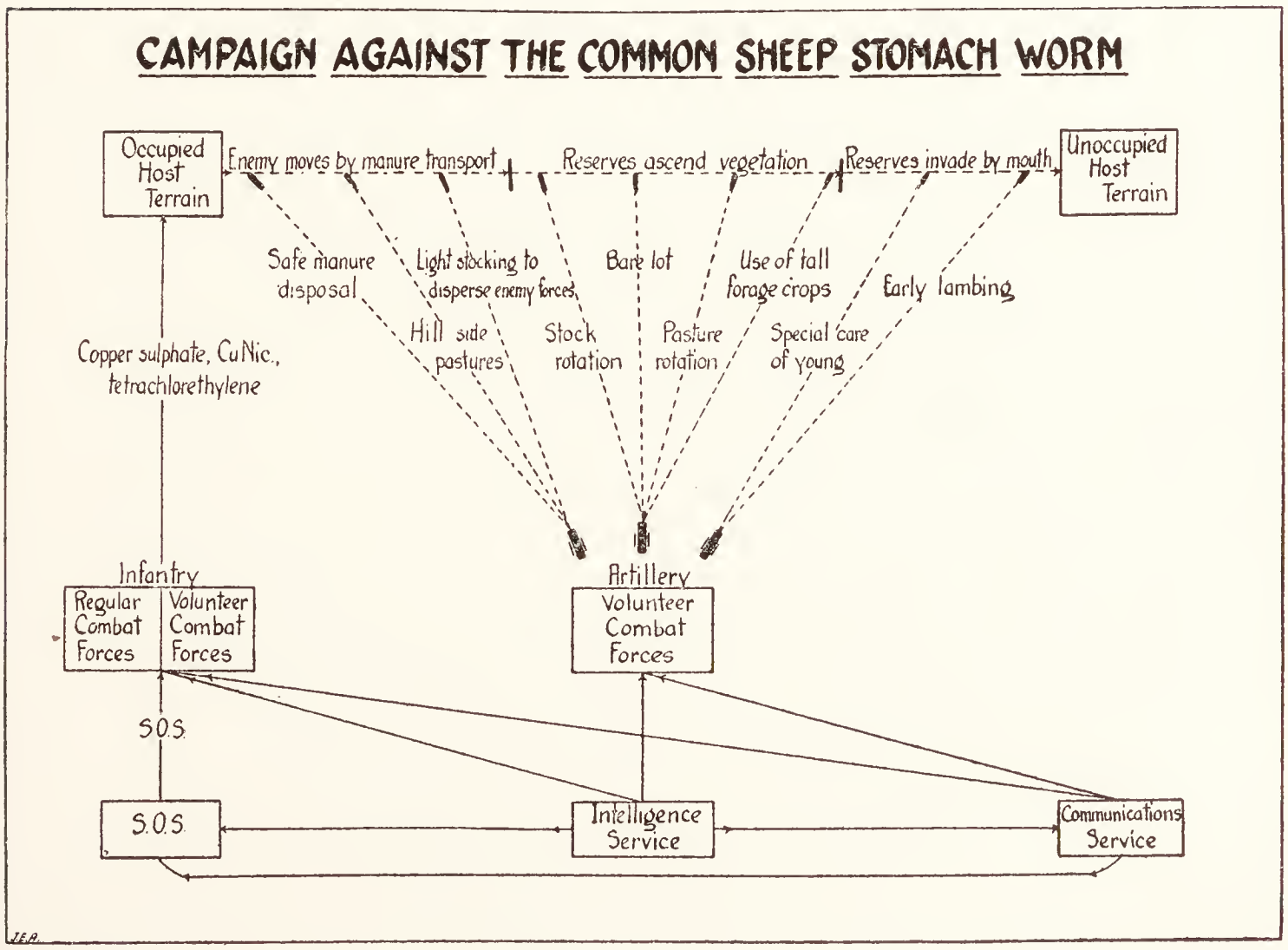
Rudolphi, one of the first of the intelligence officers of the early days of our war on parasites, first detected this enemy and named it *Strongylus contortus.* Later, Cobb, impressed by the special weapons of this enemy, called it *Haemonchus,* naming it from the spear it bore. Ransom first studied the tactics and strategy of *Haemonchus contortus.* He found that the adult enemy forces, holding positions under the folds in the abomasum of sheep, produced eggs which moved by manure transport from host terrain to pasture terrain, and hatched on the new terrain, under favorable conditions. The larval *Haemonchus* molted twice, and retained the cuticle of the second molt as an armor affording protection against destructive weather conditions. Under favorable condi-

tions, the transition from the egg in fresh manure to the armored third-stage larva, ready for the attack on a new host terrain, requires about 3 weeks. These ensheathed larvae, the reserves for the next engagement, prepare for the attack by crawling up blades of grass whenever the presence of rain or dew makes it possible for these troops to travel. On the tips of grass blades, these reserve forces coil up in ambush, and await a chance to attack. The chance comes when sheep (or goats, cattle, deer, or other ruminants) swallow the enemy-infested grass while grazing. The larval forces invade the abomasum, transform to fourth-stage larvae, and then to adults, and attack the walls of the abomasum with their spears. They also produce fresh crops of eggs in preparation for the conquest of new territory.

Military Aspects of Campaign

1. *Identity of enemy forces.* The enemy has already been identified as the Common Sheep Stomach Worm, *Haemonchus contortus.*

2. *Strength of enemy forces. H. contortus* holds a large amount of host and pasture terrain in the United States, especially in the East, South, and Middle West. It has a lesser grip on the north-



ern states, largely because weather conditions in the form of cold winters are unfavorable for enemy operations over a large part of the year, as they were for Napoleon's invasion of Russia. The enemy holds little territory in the Rocky Mountain states, because a dry climate is added to cold winters as an additional unfavorable condition, but in irrigated districts the enemy is making some headway. Why the Common Sheep Stomach Worm has not captured the West Coast states is not clear. There are abundant warmth and moisture over much of that area, and one can only conclude at this time that the prevalent west to east movement of hosts has not provided favorable and adequate host transport, as an east to west movement would have done.

3. *Positions held by enemy.* The enemy holds positions in the abomasum in host terrain, and also positions on pasture terrain, including the position on grass or other vegetation from which an attack can be launched secretly and silently. Lines of transport are by manure, land, vegetation, and to some extent, water and air. In this connection, it must be kept in mind that the obvious lines of transport are not necessarily the only ones. During heavy rains, eggs and larva are washed about and may travel for long distances. In dry weather, eggs and larvae in manure and soil may be blown for miles.

4. *Forces available against the enemy.* Contrary to what has been true in most of the campaigns already discussed, we have available in this campaign an adequate infantry force, not all of it engaged, but adequate if it were engaged, armed with a variety of quite effective weapons, and, on the other hand, we have an inadequate artillery service for cutting the enemy lines of communication. The regular infantry, the practicing veterinarian, is equipped to drive the enemy from its host terrain, but not enough of these regulars are actually engaged against the army of Parasites of Sheep. In addition to these regulars, there is a much larger force of volunteers, the farmers and stockmen, who are actively engaged in the war on *Haemonchus contortus.*

At this time the Diplomatic Service and the federal, state, county and city artillery forces are not actively engaged. Such artillery as is brought to bear on the enemy lines of communication is manned by the same forces that make up the volunteer infantry. The Service of Communications functions rather effectively in keeping volunteer forces informed and holding them in the field,

and the S. O. S. maintains an adequate supply of effective weapons and ammunition.

5. *Weapons available for the attack on the enemy.* As noted above, the infantry has an adequate supply of weapons for driving the enemy from the host terrtain. Copper sulphate was brought out and given a field test by Hutcheon; Hall and Foster gave it its first critical test and their results indicate that it is about 99 per cent effective; Skrjabin and Schulz have recently reported that it has been adopted in the U. S. S. R. as the weapon against *Haemonchus* on the basis of its efficacy, safety, and cheapness. Hall and Shillinger found carbon tetrachloride very effective; it was as effective as copper sulphate against *Haemonchus,* and more effective against some other units in the army of Parasites of Sheep. Subsequently other intelligence officers found that it damaged the host terrain under some conditions. Hall and Shillinger found tetrachlorethylene effective, and many tests have shown it to be safe. Sir Arnold Theiler found a powder composed of copper sulphate and sodium arsenite effective. Lamson found nicotine sulphate effective, and Curtice found CuNic (a copper sulphate and nicotine sulphate mixture) effective against *Haemonchus* and some other enemy forces attacking sheep.

As regards our artillery forces, pasture rotation is a maneuver whereby we cut off the enemy forces from the reserves and bring the reserves under fire by starvation, drying, and freezing. However, the armored reserves begin the invasion of the new host terrain, under favorable conditions, in 3 weeks after they leave the old host terrain in the form of eggs, and it would be necessary to move infested sheep to pasture terrain unoccupied by enemy reserves once every 3 weeks except during the season when freezing weather is more or less prevalent, and not to return to a previously occupied pasture terrain within a year. This calls for more land and fencing than the sheep industry can supply and still show a profit. As matters stand, we can move only as often as possible, on the ground that every such move is beneficial.

A variation of this rotation system is the English and Scotch system of hurdling, the hurdle being a movable fence. Under this system both sheep and fences are moved. It is a system which fits in well with a land of well trained sheep dogs, small flocks, and a somewhat leisurely mode of life, but it has never been adopted in the United States where conditions are different.

Rotation of stock on pastures is a maneuver which has been much recommended, but very little tested by our Intelligence Service. There is the possibility that when the enemy reserves invade unfamiliar host terrain, they are destroyed by virtue of their inability to adapt themselves to new and unfamiliar conditions, and by virtue of the host's defenses and its destructive counter offenses. Theoretically a suitable sequence of animals on pasture might have much more than mere defensive value and might accomplish more than a mere cutting of enemy lines of communication; it might result in the destruction of the enemy reserves.

Another form of attack on enemy reserves is the burning over of pastures annually or oftener. As regards the value of this maneuver, one may say that it is of value under certain climatic conditions and on certain terrains, where the procedure keeps back a jungle and allows established trees to maintain themselves, uninjured by the grass fire. Under some other conditions, burning over a pasture might be a serious tactical blunder.

A maneuver which the writer has suggested as of probable value in cutting the lines of transport of the enemy reserve forces, is the use of tall forage crops in lieu of short grass. At the present time short grass pastures and pastures of *Lespedeza sericia* are being prepared at Beltsville, Md., as a testing ground on which to ascertain the value of this maneuver. The eggs produced by the enemy and passing in the manure, will hatch on pasture, and the young larvae will molt to third-stage larvae with the defensive armour of the reserve forces. These enemy forces climb vegetation as a preliminary to attacking new hosts. Bond notes than "More attacks go wrong by failure to maintain proper direction than from any other cause." Theoretically, substituting tall, much branched lespedeza for short, straight grass should offer abundant opportunity for enemy reserves to lose direction and to go astray on lower branches of the lespedeza remote from where sheep are feeding on the upper branches. The factors of time and space may work to keep these reserves from ever attacking. "Time always works to nullify our success," and this is as true of the parasites' success as of ours.

Another possible line of attack on the enemy reserves is an artillery attack by chemicals. The writer has had in mind that copper sulphate could be sprayed on the pasture terrain with a

resultant destruction of a large part of the enemy reserve. Hall and Cotton tested the safety of this maneuver, using small sprayed pastures with one horse, one cow and one sheep on each of them at a time. The maneuver appeared to be quite safe for these animals. Tests of the effect on the enemy were not made, but it is hoped to test this effect soon.

Another set of maneuvers is along the line of affording special protection to lambs, since these animals are more readily attacked and more heavily invaded, and have less defense in the way of immunity than older sheep. One maneuver is that of the "bare lot" as devised by Dalrymple. This is designed to cut the enemy lines of communication at the point where the armored reserves ascend vegetation, the maneuver consisting in removing all vegetation from the terrain occupied by the lambs, thereby preventing grazing. The ewes are kept from this terrain except at nursing time, thereby diverting the enemy lines of transport by manure to other termini. Clean water is furnished, and the lambs are fed safe cut feed in raised racks. This maneuver, devised to control the Nodular Worm, is a sound stratagem against *Haemonchus* or other monoxenous worms using the same general lines of communication.

Another maneuver, designed to protect lambs, consists in placing the lambs and mothers on clean pastures, if possible, but in any case on high, dry hillside pastures. On such pasture terrain the enemy forces are at a disadvantage. They are engaged over an area exposed to the lethal weapons of the sun, the slope ensures drainage and in default of moisture the eggs do not hatch and the larvae perish, in effect, of thirst, or when it rains the eggs and larvae on the slopes are washed away by the rain. For hundreds of years shepherds have noticed that sheep thrive in hill country, not knowing that the hills afforded a terrain not only favorable to sheep, but unfavorable to the army of Parasites of Sheep. To get the full benefit of this maneuver, the pasture terrain should be occupied only in such force as will make overgrazing unnecessary; in other words, light stocking should be practiced. Heavy stocking makes it certain that a very large number of enemy transport lines will find their intended terminus in a new host terrain; light stocking leaves many of these lines ending on a grass blade, with the line certain to be cut by old age, cold, dryness or some other destructive weapon.

Another maneuver consists in lambing very early, before the spring weather permits of enemy movement, thereby allowing the lambs to attain an age at which they have some immunity defenses against their enemies before being sent into action.

6. *Plan of campaign.* The plan of campaign, so far as it can be outlined at this time for an army made up mostly of volunteers, would be as follows:

(1) The regular infantry to attack the enemy in host terrain whenever possible, using any of the effective weapons available.

(2) The volunteers to attack the enemy in host terrain whenever the regulars cannot be engaged, using the safest of the weapons available.

(3) The volunteers to carry out any of the maneuvers mentioned for cutting the enemy lines of communication, or any similar maneuvers, whenever possible.

7. *Results of campaign.* The present campaigns contemplate no decisive victories with the enemy driven from the field and his forces annihilated. In our battles on the host terrain we can destroy the vast majority of enemies present, but we leave a few to organize a later counter attack. We can almost, but not quite, "Shoot the enemy out of his position." Moreover, so far as our infantry attack is concerned, we leave the enemy reserves intact and ready to attack the next day. Nevertheless, from the standpoint of the volunteer infantry, this campaign is a success. To any one who has seen a flock of sheep with two or three animals succumbing daily to the attack of *Haemonchus,* and seen these deaths stop and the enemy finally routed by copper sulphate, the campaign is a success. It makes the difference between profit and loss in the sheep business.

Nevertheless, we expect some day to declare a war of annihilation on *Haemonchus.* For that war we shall need better weapons, or better tactics and strategy, or more men and money, or, perhaps, all of these things. It is the business of the Intelligence Service to develop the weapons, and to formulate the tactics and strategy. If more men and money are needed, the live stock industry, in one way or another, will have to provide it.

A Stalemate in the War on Anaplasma

It has been noted that when Theobald Smith carried out his reconnaissance against the Piroplasm causing southern cattle fever, he identified the enemy as *Piroplasma bigeminum,* and that actually he was dealing with three enemies. A distinguished intelligence officer, Sir Arnold Theiler, showed, some years later, that the marginal dots which Smith regarded as part of the forces of *Piroplasma bigeminum,* were actually another enemy unit, *Anaplasma marginale,* and our American comrades in arms, Rees and Becker, found that the piroplasms which Smith found attacking our American cattle, were actually composed of two different units, *P. bigeminum* and *P. argentinum.* Smith's report was quite natural at that early date, and must be regarded as the only one warranted by the facts collected in his reconnaissance.

On the basis of the reports of Smith and other members of the Intelligence Service, a campaign against *Piroplasma bigeminum* is being brought to a successful conclusion along the lines of destruction of enemy lines of communication through transport by the Cattle Fever Tick, *Boophilus annulatus,* and its ally, *B. annulatus australis.* It was assumed on the basis of the facts available at the beginning of the campaign, that the destruction of the tick would destroy the enemy groups regarded at that time as one unit, *P. bigeminum.* It now appears that the destruction of *B. annulatus* and *B. a. australis* results in the destruction of *P. bigeminum* and *P. argentinum,* but not of *Anaplasma marginale.*

The fact that *Anaplasma* was moving out of the war zone where the Cattle Fever Tick was under fire, over some unknown lines of communication, was brought to our attention in 1924 and 1925 when the veterinary officers, E. P. Flower of Louisiana and Wm. Boynton of California, reported anaplasmosis from Louisiana and California cattle in areas that had been free from the Cattle Fever Tick for years. In rapid succession other similar cases were reported by intelligence officers and veterinary combat officers. The enemy had invaded and was holding areas in the North in which the Cattle Fever Tick had never been able to maintain its forces over winter, and was holding many positions in the area formerly held by the Cattle Fever Tick, but from which it had been expelled. *Anaplasma* was established in Cali-

fornia, Nevada, Kansas, Oklahoma, Louisiana, Florida, and elsewhere, out of the territory held by the Cattle Fever Tick.

This was a critical situation. The enemy had quietly infiltrated into our territory and was taking new positions and consolidating old ones. The Communications Service broadcast warnings to all forces to put out patrols and to maintain contact with the enemy. Federal and state intelligence officers were dispatched to various points to ascertain the lines over which enemy forces were moving. Reports from Boynton, Dikmans, Rees, Stiles and other members of the Intelligence Service presently showed that this enemy moved over many lines of communication. Boynton, Hilts, and Dikmans observed that the enemy seemed to move rapidly from the terrain of one definitive host to that of another definitive host by mechanical transport, using hypodermic needles, lancets, dehorning instruments and similar things, and Rees obtained experimental evidence to this effect. Rees reported that in addition to *Boophilus annulatus* there were other ticks which would serve to carry enemy forces from one definitive host terrain to another, these ticks including *Rhipicephalus sanguineus, Dermacentor variabilis, D. andersoni,* and *Ixodes scapularis.* Stiles, Moe, Orr and Sanborn, and Sanders showed that biting flies, including *Tabanus aequalis, T. gracilis, T. fuscicostatus, T. sulcifrons, T. venustus, T. fumipennis, Chrysops sequax, Sylvius pollinosa* and *Stomoxys calcitrans* could carry enemy forces mechanically.

Military Aspects of Campaign

1. *Identity of enemy forces.* The enemy force is known as *Anaplasma marginale.* This enemy is of a somewhat peculiar sort, and the Intelligence Service is still uncertain as to the nature of its force. Tentatively this force is regarded as protozoan, but it is not definitely protozoan.

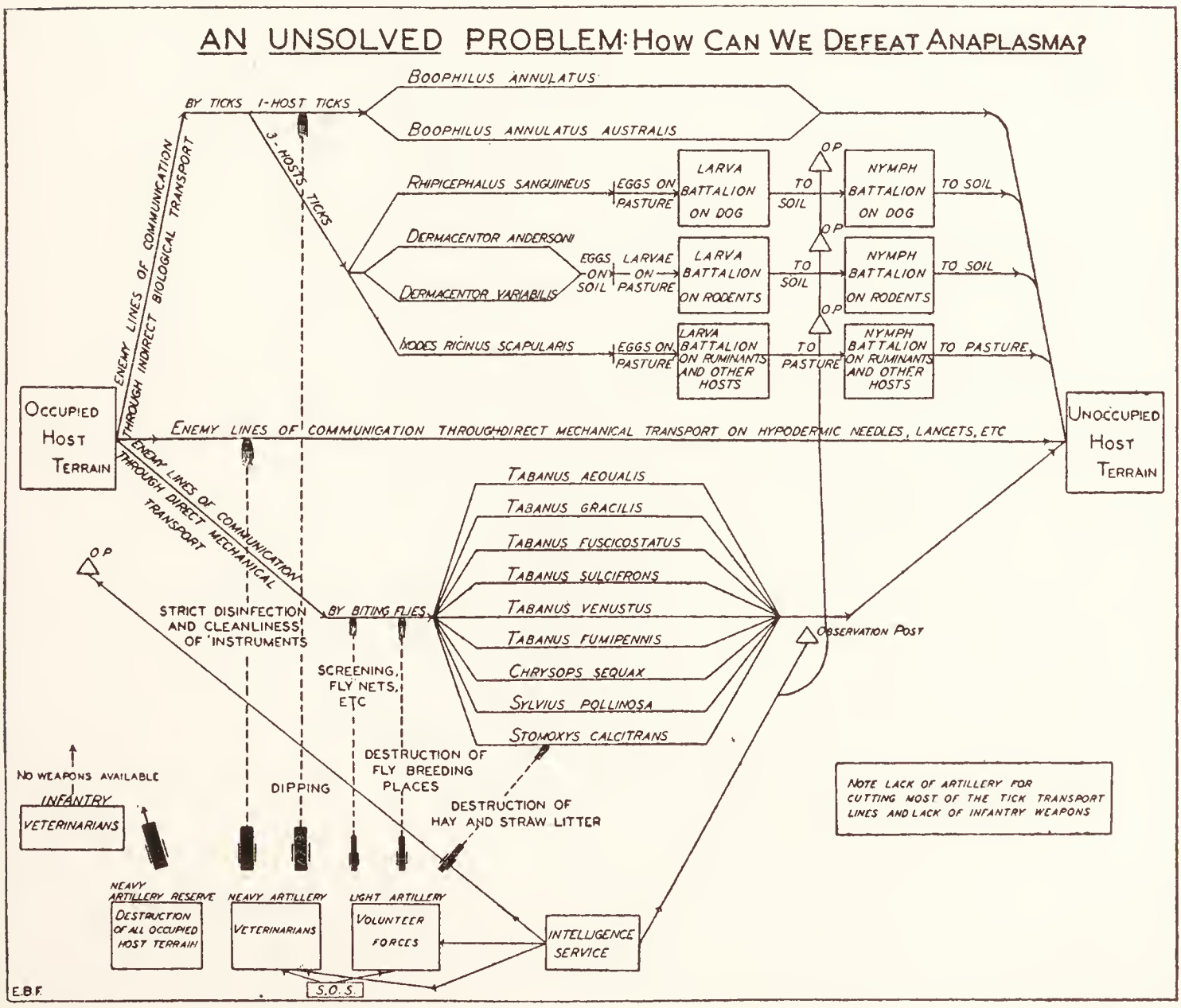
2. *Strength of enemy forces. Anaplasma* holds scattered areas over the United States, not a solid area such a *Piroplasma* held. The difference in the areas held is apparently due to the fact that the two forces advance over very different lines of transport. *Piroplasma* moved mostly by transport furnished by *Boophilus annulatus,* a tick that held a solid, well consolidated area, sharply delimited by climatic factors. *Anaplasma* can move by many lines of transport, and is at present still invading new areas, its advance guards pushing forward at widely separated points. At present it is known to be in California, Nevada, Colorado, Kansas, Okla-

homa, Louisiana, Mississippi, Alabama, Georgia, Florida, Texas, Wyoming, and Delaware, and has probably invaded other areas in which it has not yet been detected.

3. *Positions held by the enemy.* *Anaplasma* holds positions in definitive host terrain in cattle, and has been shown to be capable of holding similar positions in sheep and deer, apparently doing little damage in these terrains. It also holds positions in six species of ticks and in 9 species of biting flies, all affording it shelter and transport.

4. *Forces available against enemy.* At this time the Intelligence Service is conducting reconnaissances of the enemy on several fronts, studying its nature, its lines of transport, and other things. Veterinary Combat Forces, with inadequate weapons, are conducting local skirmishes here and there. Other forces that might be used are in reserve or engaged against other enemies, and no organized campaign is under way at this time.

5. *Weapons available for attack on enemy.* For the direct



attack on the enemy in the definitive host, we have no adequate weapons of known value. Various drugs are recommended, but no evidence is available showing that enemy forces under fire from these weapons are destroyed, or that they yield ground under this fire any more rapidly than before the counter attack of the host's defensive forces. No serological weapons have yet been shown to have offensive value in driving back *Anaplasma* after it attacks.

Our artillery weapons include some heavy artillery, weapons which are in actual use and dependably effective for cutting enemy lines of transport, and some light artillery, weapons of potential value in interfering with enemy transport, but not so practical or sound or generally effective as to be dependably effective in cutting enemy lines of transport. Our heavy artillery includes dipping cattle, a dependable weapon in destroying enemy lines of transport by one-host ticks, and strict cleanliness and disinfection in destroying enemy lines of transport by hypodermic needles, lancets, dehorning instruments, etc. Our light artillery includes screening and fly nets, weapons of very limited value in cutting enemy lines of transport by biting flies moving from one definitive bovine host terrain to another, and destruction of fly breeding places, another weapon very little developed for use in preventing transport by tabanids, and the burning of hay and straw litter, a weapon of some value in preventing transport by stable flies.

A big gun which is not yet in action, and which cannot be used until the Intelligence Service furnishes further information, is the weapon afforded by destruction of all invaded host terrain. This will be discussed in more detail later.

6. *Plan of campaign.* It is obvious that with no adequate infantry weapons, and with no artillery or only very light weapons for destroying some of the many enemy lines of transport, we are as yet in no position to wage effective warfare against *Anaplasma.* The odds are all against the winning of such a war if we start it, and it is unsound strategy to declare war with every prospect of defeat.

The most promising campaign, so far as can be foreseen at present, would be one contingent on the development by the Intelligence Service of a method of ascertaining, quickly and surely, the presence of *Anaplasma* in invaded host terrain, even though

all of the signs of combat had died down, and the enemy was no longer raiding in large numbers along the highway of the blood stream and could no longer be detected in a reconnaissance along that highway. If the Intelligence Service can furnish this method, so that we can find the enemy, quickly and surely, in every invaded host terrain, it will then be possible to bring into action the highly effective weapon of destruction of all invaded host terrain, the same weapon that has been used so effectively in the campaign against tuberculosis. With this weapon it would evidently be possible to carry a sound campaign to a successful conclusion with the annihilation of the enemy forces as our objective. At the moment the campaign is a stalemate, but work under way in the Bureau of Animal Industry indicates that the Intelligence Service may soon be in a position to recognize an invaded host terrain, even in the absence of visible enemy activity. If it is successful in this, it will make possible the use of the weapon which cannot at this time be brought into action, eradication by slaughter.

The Campaign Against the Beef Tapeworm, *Taenia saginata*

Man has developed certain sanitation weapons of a sort that may be regarded as heavy artillery of all around usefulness, valuable in combat not only against parasites but also against many other pathogenic enemies of man. Because of their great value these weapons are constantly in use in our incessant warfare against disease, and serve to destroy our parasite enemies regardless of whether we are consciously directing them to that end at this time or are simply continuing their routine use to combat disease in general or for other purposes. Three of the most valuable of these weapons are proper disposal of human feces by means of sewers or privies, efficient meat inspection, and the thorough cooking of meat. In our combat against the Beef Tapeworm of man, *Taenia saginata,* which has its larva, *Cysticercus bovis,* in cattle, all these weapons are constantly employed, and, in default of a well organized campaign definitely directed against this parasite, we are keeping this enemy in check precisely to the extent that these effective weapons are in action. The campaign against the tapeworm is a detail of a campaign against disease.

Findings of the Intelligence Service

The Beef Tapeworm and its larva in cattle have been known for many centuries. Goeze called it *Taenia cucurbitina saginata* in 1782, and Leuckart called it *Taenia saginata* in 1867. *Cysticercus bovis* was so named by Cobbold in 1866. Leuckart in 1861 first showed that this enemy moved from man to cattle, establishing this by feeding tapeworm segments containing eggs to cattle and recovering the cysticercus from the cattle, and a few years later Oliver and also Perroncito and his students showed that it moved from cattle to man, establishing this by swallowing the cysticerci and developing the adult tapeworm in the human intestine.

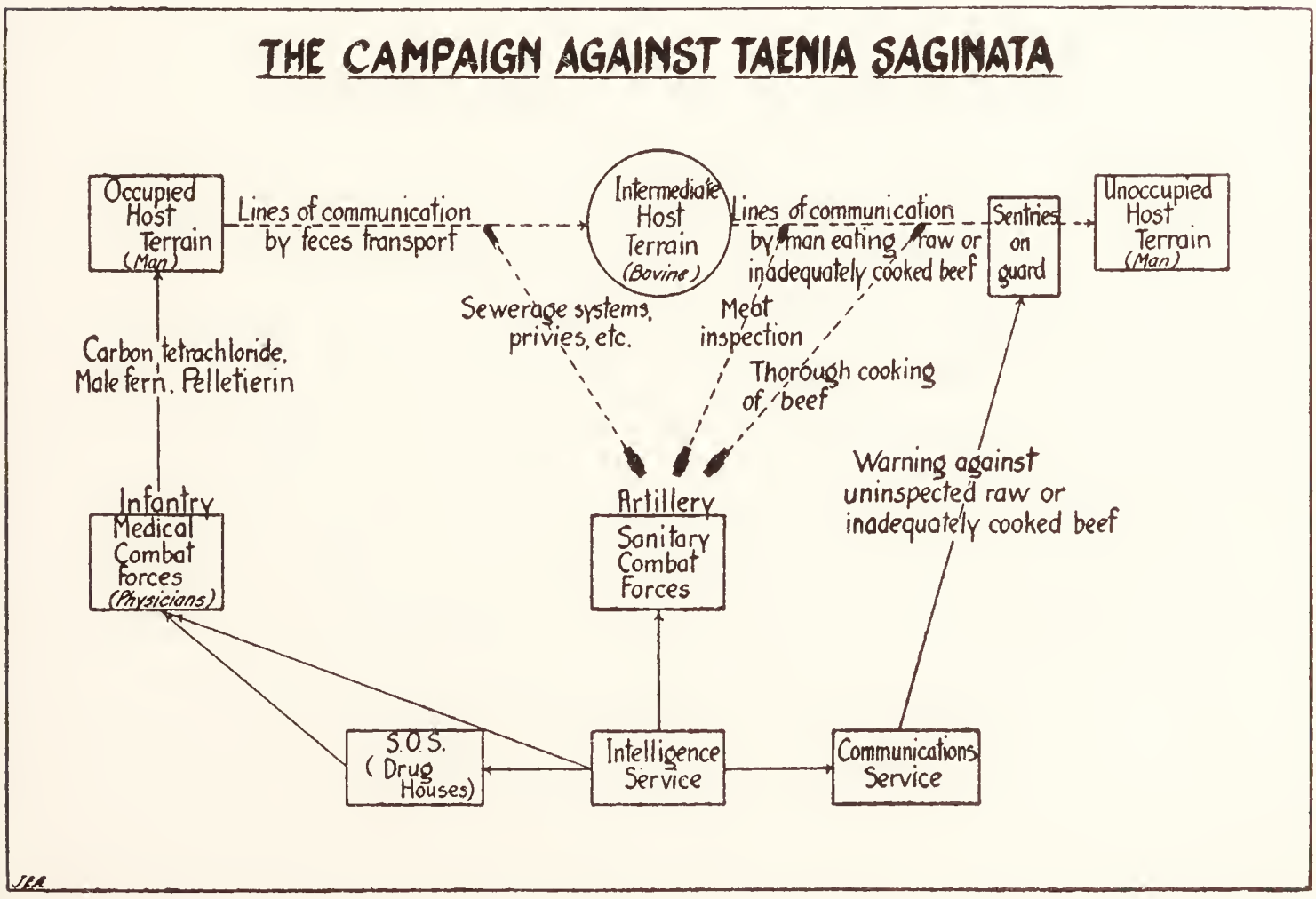
Military Aspects of Campaign

1. *Identity of enemy forces.* As noted, the enemy is *Taenia saginata,* a large tapeworm occurring in the small intestine of

man and having a bladderworm larva known as *Cysticercus bovis* in the muscles of cattle.

2. *Strength of enemy forces.* This enemy holds scattered areas over the United States, and is usually present in small numbers in these areas. The Federal Meat Inspection Division furnishes the following figures for bovine cysticerosis for the years indicated, the per cent being that based on total killed for federally inspected cattle: 1912—10,968 (0.14 per cent; 1920—28,403 (0.29 per cent); 1928—28,696 (0.31 per cent; 1929—28,386 (0.34 per cent); 1930—31,231 (0.37 per cent); 1931—27,171 (0.33 per cent); 1932—22,368 (0.28 per cent); 1933—21,068 (0.27 per cent).

The figures given indicate that by means of the weapons named, using these for general purposes and with no definite campaign under way to eradicate the Beef Tapeworm, the enemy held positions in about 14 to 37 bovine hosts out of every 10,000 inspected under Federal supervision. They also indicate that from 1912 to 1930, the enemy gained ground, occupying over 150 per cent more territory in 1930 than in 1912. The enemy lost ground after 1930, but still has about twice as much host territory as in 1912. The reasons for our loss of ground from 1912 to 1930, and our gain from 1930 to 1933, are not evident.



The geographic distribution of the enemy forces cannot be accurately ascertained from meat inspection records, since the city in which the animal is slaughtered does not necessarily mean that the infection was acquired in the state in which the city is located. The records for 1912 and 1933 show no cases from cattle slaughtered in Maine, Vermont, New Hampshire, Connecticut, Rhode Island, Delaware, North Carolina, South Carolina, Mississippi, Louisiana, Arkansas, and New Mexico, but this cannot be taken to mean that the parasite was not present in human or bovine hosts in these States.

3. *Positions held by enemy.* The Beef Tapeworm holds positions in the small intestine in the human terrain; on soil, pasture, etc., while in the egg stage; and in the muscles in the bovine terrain. It invades the bovine host as the host swallows the tapeworm eggs in feeding on pasture or drinking water contaminated with these eggs, and invades the human host as the host eats raw or inadequately cooked beef containing the cysticerci.

4. *Forces available against the enemy.* There are available adequate infantry forces in the form of practicing physicians for attacking the enemy in the human terrain. There are available over most of the country adequate artillery forces in the form of health officers, veterinarians, sanitary engineers, and other groups competent to man our sanitary weapons.

The proper disposal of human feces is being effected to a constantly increasing extent. A number of factors have been responsible for this. One factor is the better economic status resulting from an economy of plenty in spite of faulty distribution of that plenty. Better economic conditions result in higher standards of living. Another factor is the increasing amount of automobile tourist travel. Dr. Charles Wardell Stiles has pointed out that the custom of providing comfort stations and rest rooms at gasoline filling stations has resulted in setting an example to the people of rural areas adjoining these stations, and accustoming them to the use of privies and toilets in regions where there was still a large amount of soil pollution. In this connection, there is another feature of the automobile tourist trade which is of importance, and that is the enormous number of homes in small towns and rural districts which have overnight tourist accommodations. All other things being equal, owners of houses without sanitary provisions are at a disadvantage in competition with

owners of houses having these provisions, and owners of houses with inferior provisions are at a disadvantage in competition with owners of houses having superior provisions. The effect of all the above factors and certain others is to increase the number of homes having sanitary provisions and to better the existing provisions.

As regards the extension of a sound meat inspection system, the status is improving. According to estimates made by the Federal Bureau of Agricultural Economics, a little less than 50 per cent of the cattle (excluding calves) slaughtered in the United States in 1900 were inspected by the federal service. For the years noted above, the figures are: 60 per cent in 1912; 62 per cent in 1920; about 67 to 68 per cent for 1928-1930; and about 63 to 64 per cent for 1931-1932. As regards inspection under state supervision, California stands alone as a model in this respect. As regards city inspection, it is usually inadequate or incompetent; only a few cities, such as St. Louis, have an inspection comparable to the federal inspection. However, the examples of California and St. Louis will be followed by other states and cities sooner or later.

As regards the thorough cooking of beef, it is doubtful if the situation in this respect has changed perceptibly during the past 30 years. The large number of persons who eat raw or rare beef will probably continue to do so, and will be protected against the attack of the Beef Tapeworm only as they eat beef from houses under adequate inspection. Those who eat well-cooked beef will be protected by this cooking regardless of the source of the beef.

5. *Weapons available for the attack on the enemy.* Our infantry, the practicing physician, has adequate weapons in his armamentarium for the direct attack on the enemy in the human host terrain. Male fern, Tanret's pelletierin, carbon tetrachloride and other drugs are effective weapons. They will not drive the enemy from the intestine in all cases, and it is necessary at times to renew the assault once or twice to secure victory, but they are effective.

As regards the parasite in the bovine host terrain, we have no weapons in the form of drugs for its destruction. Surgical attack is impossible or impractical.

Our artillery weapons, sanitary systems in the form of sewerage systems and privies, competent meat inspection, and thorough

cooking of beef, have already been discussed. These weapons are effective, and the failures in our campaign against the beef tapeworm are due to failure to employ these weapons.

6. *Plan of campaign.* At present we have no organized campaign against the Beef Tapeworm. Since the weapons which are of the most value are those generally valuable against disease and parasites of many kinds, our efforts should be directed to securing the more general use of these weapons on the broad basis of sanitation essential to civilized life.

Federal meat inspection is extended more or less automatically, since it rests on the basis of interstate commerce and is compulsory for meats entering into such commerce. State and city inspections are installed or approved only as there is a demand for such things or a realization of their value. The inadequacy of city meat inspection in general follows usually from the fact that the inspectors are likely to be of the political and often non-professional type, rather than the non-political professional type, and the inspection regulations are of the casual sort dictated by political and commercial expediency. To remedy this situation, veterinarians, physicians and the more thoughtful citizens generally should demand adequate inspection for all meats. They should insist also that the political basis of selection for professional and other state and city employees be abandoned and that the public select its employees on the basis of a merit system.

It has already been pointed out that the automobile is playing a large role in improving sanitation in small towns and rural districts, so far as safe disposal of human feces is concerned, and it is probable that the shuffling of population by auto travel will continue to result in general improvement in this respect as the result of a general demand by tourists for such improvement. Almost no part of the United States escapes the effect of this factor.

It has been noted also that changes in food habits as regards cooking are not to be expected. Here the logical line of attack is to insist on the importance of adequate meat inspection for the protection of a nation which to a large extent prefers rare beef.

7. *Results of campaign.* In effect, our campaign against the beef tapeworm is a purely incidental affair, not a definite and separate campaign directed towards the destruction of this enemy,

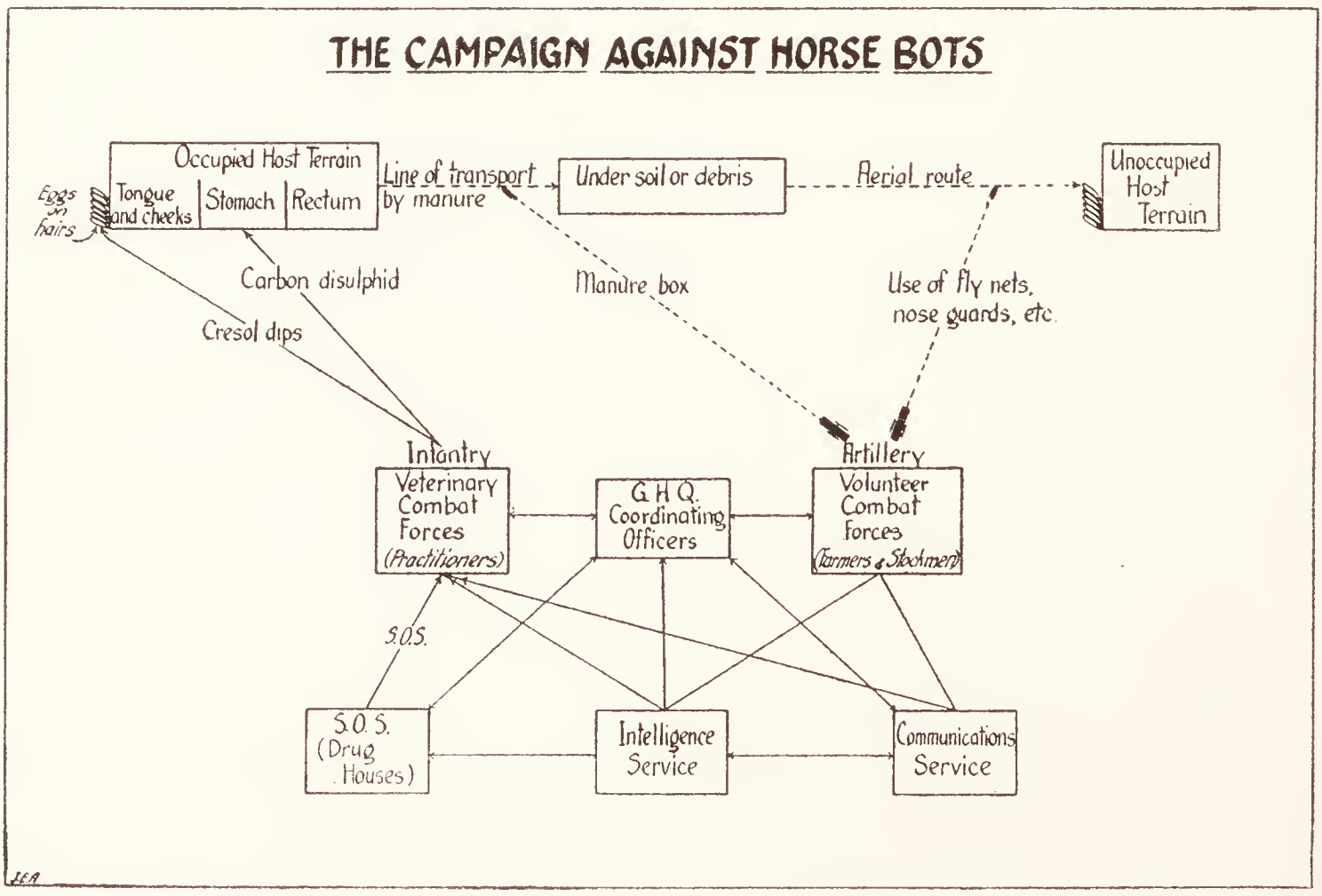
but part of a general campaign against disease. Apparently we are holding the enemy to a relatively small territory, and there is the reasonable expectation that a wider use of weapons now in use to some extent, will drive the Beef Tapeworm back. Of the weapons most likely to be used more extensively, the wider employment of toilets and privies in rural districts seems most probable. It is especially desirable that such facilities be provided around feeder yards. The federal meat inspection service traces cases of bovine cysticercosis to point of origin whenever possible, and points out to feeders the action they should take in providing toilet facilities and compelling employees to use them, and also points out that cattle buyers will discriminate against feeders known to supply cattle which have cysticercosis; and this practice of the meat inspection service results in the treatment of cases of tapeworm infestation as well as in the installation of toilets and insistence on their use.

The case of the beef tapeworm illustrates admirably the military principle that there is nothing to be gained by cutting the enemy lines of communication and then restoring these lines of communication. Ransom published a report of feeder cattle grossly infested with *Cysticercus bovis* and traced back to a feed yard in which the following condition existed: The feed yard was located on the banks of a stream, and the water for the cattle was pumped from the stream at a point a short distance below the outlet of the sewer from a neighboring town. The evident effect of such an arrangement was to restore the line of communication of the parasite from man to cattle after the sanitary weapon of a sewerage system had been employed to sever these lines. Recently a case has come to the writer's attention in which the sewage from a city was used to fertilize a pasture on which cattle fed. The cattle had cysticercosis. The question was raised as to how to prevent this. Here again we have the rather illogical situation of restoring the parasite's lines of communication after our sanitary weapon has severed them. It is the writer's opinion that if sewage must be used for the fertilization of pasture, the pasture should be used to graze sheep or horses, not cattle or swine, since the latter two are subject to attack by tapeworm enemies occurring as adults in man, and the former two are not.

The Campaign Against Horse Bots

The lines of communication of the Horse Bots include the invasion of the host terrain by the deposition of bot fly eggs on the exterior of the host, the hatching of the eggs and the invasion of the buccal mucosa by the young larvae, the emergence of the larvae from the mucosa and their passage to the stomach and upper part of the small intestine, the subsequent development of the larvae, their movement to the exterior, sometimes with a halt in the anal region, the development of larvae to pupae in soil or under debris, the emergence of the adult flies, mating, and the deposition of eggs on the host.

The enemy may be directly attacked in the host terrain by our Combat Forces with carbon disulphid, and effectively destroyed. The eggs on hairs may be destroyed with cresol dips or with continued use of warm water to hatch the eggs and then continued use of warm water in quantities sufficient to wash off the hatched larvae. The use of the manure box built to facilitate self-heating or to use steam for sterilization, is of value as an auxiliary weapon in the case of infestations in stabled animals. Doubt-



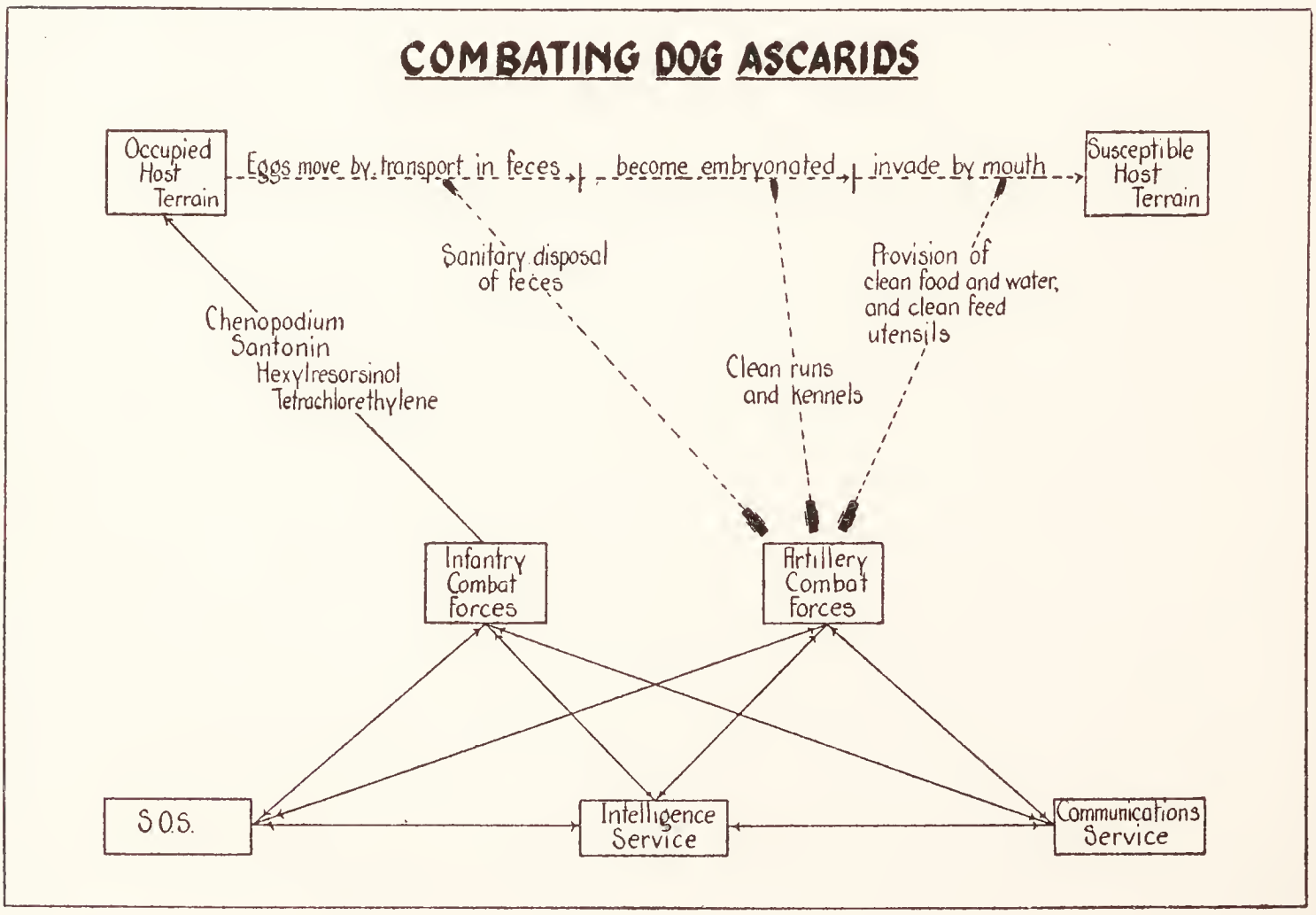
less the greatly increased use of surfaced roads leads to the destruction of many bots, since manure dropped on such roads is likely to be crushed by tires, and the bots have little chance in any case to get to points where pupation is possible. If the weapons against bots noted above are not used, such weapons as fly nets, nose guards, etc., may be used in a defensive action, but here, as is usually the case, the best defense is an offensive.

Large-scale campaigns against the Horse Bot, using carbon disulphid as the principal weapon, in Iowa, Illinois and other states, are making headway against these enemies. Infantry Combat Forces and the Service of Supplies have been active in this. An adequate extension of these campaigns would result in nation-wide destruction of the bot forces. This is a perfectly practical campaign, and there is some prospect that it will be carried out within the next quarter century.

Combating Dog Ascarids

The Dog Ascarids form the largest group of the enemy forces attacking dogs and invading a terrain deeper than the skin. This group follows the dog wherever it goes, and since the dog follows man, and man is practically ubiquitous, the combination of man, dog and Dog Ascarids is found over almost all the occupied land areas of the world. The Infantry Combat Forces, the practicing veterinarians, probably combat this enemy more than they do any other of the helminth enemies of dogs. It is true that in this or that area some other parasitic enemy of dogs may be more important than Dog Ascarids, but over the world in general the statement that a dog is "wormy" means in the majority of cases that the dog is the victim of ascarids, and "to worm" a dog means, usually, to attack and drive out these ascarids.

The adult enemy forces occupy the small intestine of the invaded host terrain, although they may wander to the bile ducts or occasionally enter the stomach and wander out by mouth or nostrils. In their movement from an occupied terrain to a new terrain, they move as eggs in transport by feces; these eggs become



embryonated and invade a new host terrain when swallowed in contaminated food, water or soil. After being swallowed, the enemy movement varies with the units making up this group of ascarids.

The eggs of one unit, *Toxocara canis,* hatch and the larval forces invade the blood stream, passing to the heart and lungs, and enter the air passages, proceeding thence to the mouth and being swallowed; on arrival in the small intestine they develop to adults. Many individuals of the invading forces of this unit are trapped in various parts of the invaded terrain and destroyed; they are quite often destroyed in the kidneys. This enemy seems prone to attack pups, and may attack them while they are in the maternal uterus.

The eggs of another unit, *Toxascaris leonina,* hatch and, according to one member of our Intelligence Service, Wright, the larval forces invade the intestinal mucosa, undergo some development in that area, and then return to the lumen of the small intestine and develop to adult enemies. This enemy seems to be more prone to attack older dogs.

In general our attack on both of these enemy units is the same. Both can be attacked successfully by our Infantry Combat Forces with such weapons as chenopodium, santonin, hexylresorcinol, or tetracholethylene. Since both move by transport in feces, our sanitation weapons in the form of sanitary disposal of feces and the provision of clean runs and kennels, clean food and water, and feeding utensils, are effective in cutting the enemy lines of communication to the extent that these weapons are used and that dogs are held within the area in which they are used. In cleaning such things as kennels, and feeding utensils, boiling water, and hot, strong cresylic disinfectants may be used effectively to destroy the parasite eggs.

The fact that *Toxocara canis* may invade the foetal pups calls for special measures to protect these pups. Bitches should be treated to destroy the adult forces of the enemy, then placed in clean quarters, then treated again two weeks later to destroy any enemy forces that have returned from wandering through the extra-intestinal terrain out of the line of fire of our anthelmintic weapons, and then held in clean quarters, safe from attack, until the pups are born. The pups should be raised in clean, safe areas.

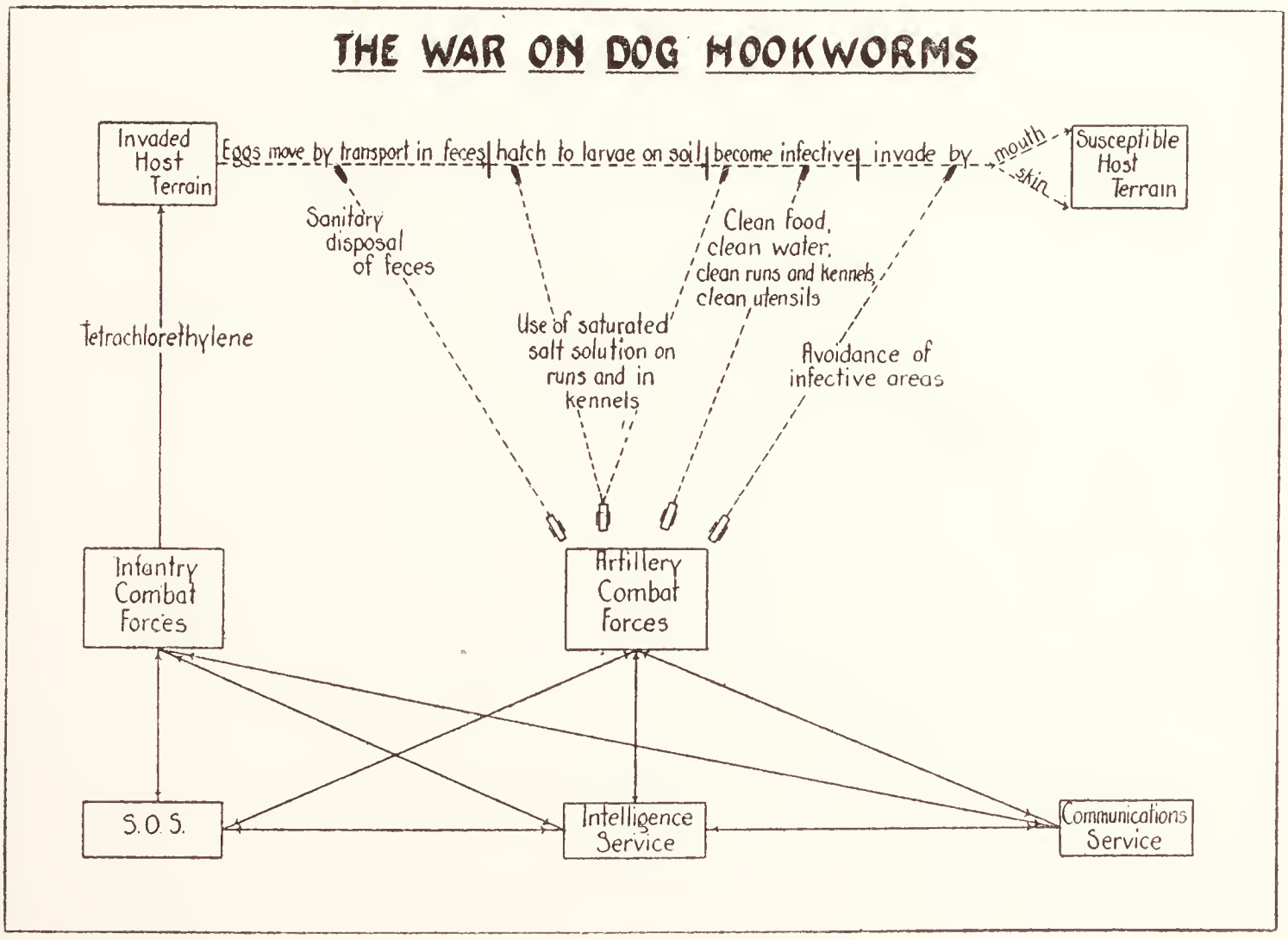
Although the Dog Ascarids appear to be holding their own

fairly well against our attacks, it seems altogether probable that our constant attacks on them have improved our situation over that of 20 years ago, when very little was being done to drive them back. At that time small animal practice was negligible by comparison with this practice today, our weapons were not well established, and the best of them were not as generally or as effectively used, and the dog-owning public was not as well educated as it is today as a result of the information supplied by the Communications Service from all sources. The continued and extended use of our weapons and our educational measures will probably result in driving back the Dog Ascarids and ultimately defeating them, although this will obviously call for a long campaign. Ownerless dogs and dogs that are allowed to run at large without the owner's care or control will be the important factor as regards the possibility of eradicating the Dog Ascarids, as these dogs will constitute a terrain which the enemy can hold safe from attacks and from which it can operate as a base in renewing attacks on other terrains.

The War on Dog Hookworms

The Dog Hookworms are almost as ubiquitous as the Dog Ascarids. One unit, *Uncinaria stenocephala,* ranges the northern areas of the world, including the polar regions, and attacks dogs and foxes. Another unit, *Ancylostoma caninum,* ranges south of the area in which *U. stenocephala* operates, covering the Temperate Zone of the Northern Hemisphere. Another unit, *Ancylostoma braziliense,* ranges the Tropical Zone and extends south into the South Temperate Zone. The range of *A. caninum* overlaps those of other dog hookworms and this enemy of dogs appears to be the most widely distributed of them all.

The Dog Hookworms occupy the small intestine of an invaded terrain and move as eggs by transport in feces; the eggs hatch and the larvae develop to the infective stage; the infective larvae may invade a new host terrain by mouth or by movement through the skin, especially through the pads of the feet. The enemy forces invading by mouth apparently can establish themselves in the lumen of the small intestine and develop to adults, but some of



these move to the blood stream and follow the route of the skin invaders. Those that invade by the skin must make their way to the intestinal lumen, and the route of march is by way of the blood stream to the lungs, by the air passages to the mouth, and down the esophagus to the stomach and so to the intestine.

The infantry weapon which is most widely used on the basis of effectiveness, safety and low cost is tetrachlorethylene. The possibility that we may drive the adult forces of the enemy from the intestine, and then find evidence that they are back again in two weeks as a result of larval forces entering the intestines after a march through the tissues out of sight and out of range of our weapons, must be kept in mind; a renewed infantry attack is necessary to support our artillery action in such cases.

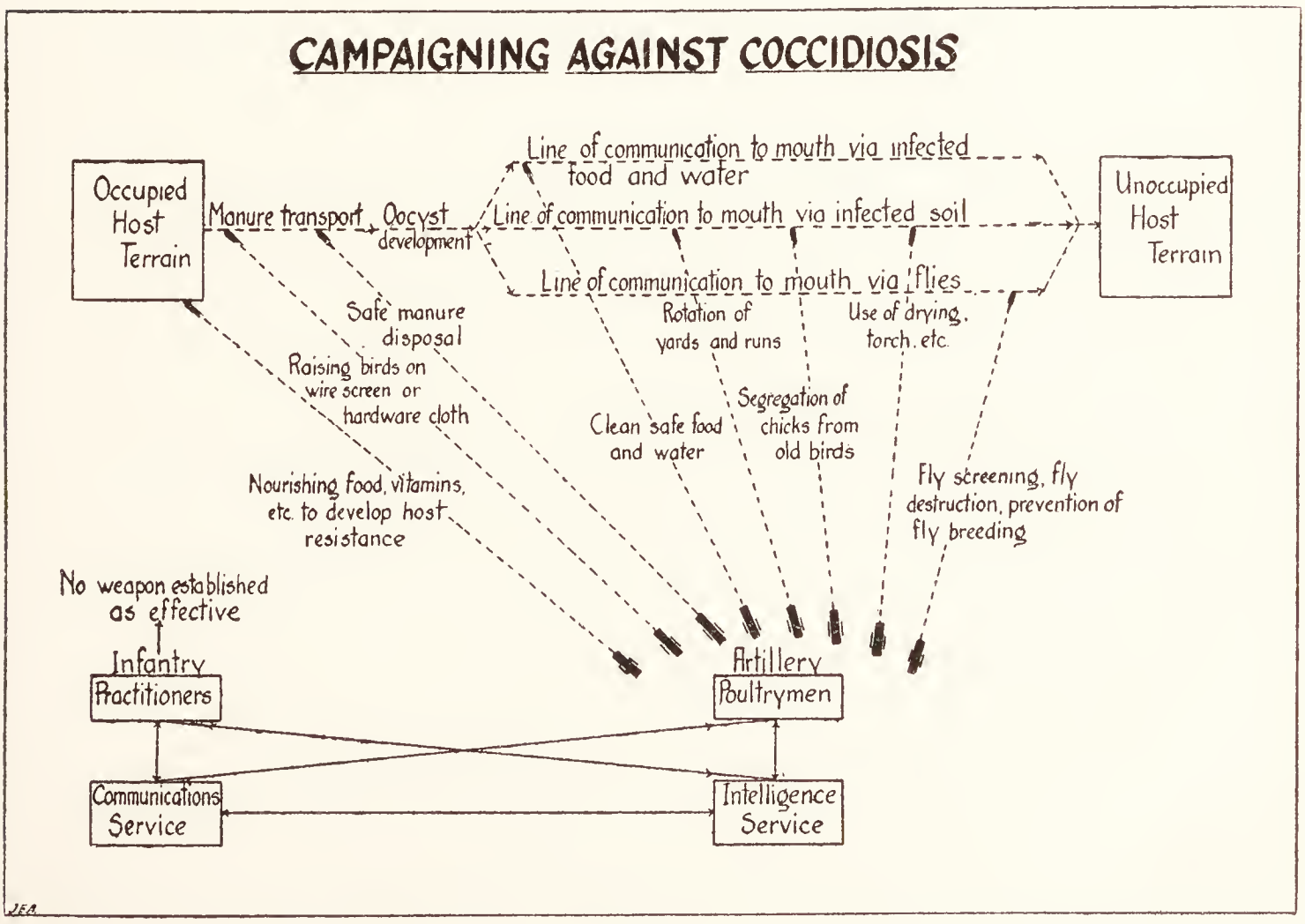
Our artillery weapons for cutting the enemy lines of communication are the same as for use against Dog Ascarids, but we have an additional weapon in the form of strong brine (NaCl) solution for use against the larval battalions of the enemy in the soil of runs. Law of the Intelligence Service has found this weapon effective against hookworms in foxes, and Underwood of the Intelligence Service has found it effective against hookworms in dogs. The finding of a weapon effective against an enemy force in soil may prove to be of great importance, as enemy forces in soil have quite generally resisted our attacks against them in this position.

Our estimate of the situation is to the effect that we are probably in a position to defeat the Dog Hookworms, and that we are making progress in this war. As in the case of Dog Ascarids, the ownerless dog and the dog neglected by its owner will provide a safe terrain for the enemy and thus make possible the constant threat of counter-attacks against the positions captured by us.

Campaigning Against Coccidiosis

Coccidia move by manure transport along the lines of infected food and water, infected soil, and flies. An outstanding feature of our situation, as regards a campaign against these enemies, is our lack of any infantry weapon established as effective by adequate test. Numerous weapons have been proposed and subsequently discarded on more careful test or still await adequate test. Our artillery weapons are numerous, but are all of the order of light artillery—of some value in hampering enemy movement but not of dependable value in cutting the enemy lines of communication.

Our present estimate of the situation is that we are not gaining ground against Coccidia, that we are inadequately prepared for a campaign because of our lack of infantry weapons and the inadequacy of our artillery weapons. Until the Intelligence Service has established more and better weapons, or better tactics and strategy, no plan of campaign can be advanced with any assurance of its success.



Defeating Dipylidium

Most of the tapeworm enemies of dogs appear to be losing ground. Aside from Dipylidium these tapeworms depend on transport in the flesh of such animals as cattle, sheep, swine, rabbits and fish. For thousands of years their lines of communication were on a sound basis. Cattle, sheep and swine were slaughtered around camps and on farms and ranches, or at small country or town slaughterhouses, and under these conditions viscera and diseased flesh were fed to dogs or thrown out where dogs had access to them. Carcasses of animals dying from disease were left to the dogs for disposal. Under present conditions most food animals are slaughtered in abattoirs in which there is at least some sort of meat inspection under which dogs cannot gain access to viscera or diseased flesh. The sanitary level on farms has risen to the point at which there is much less of the practice of feeding viscera and diseased parts of carcasses to dogs. The economic advantages of converting diseased material into fertilizer and other by-products have aided in raising the sanitary level of our mode of living. As regards fish, it is only in relatively restricted areas that dogs have access to raw fish of the kinds that carry dog tapeworms; most of the world does not provide the set-up for maintaining these parasites in dogs.

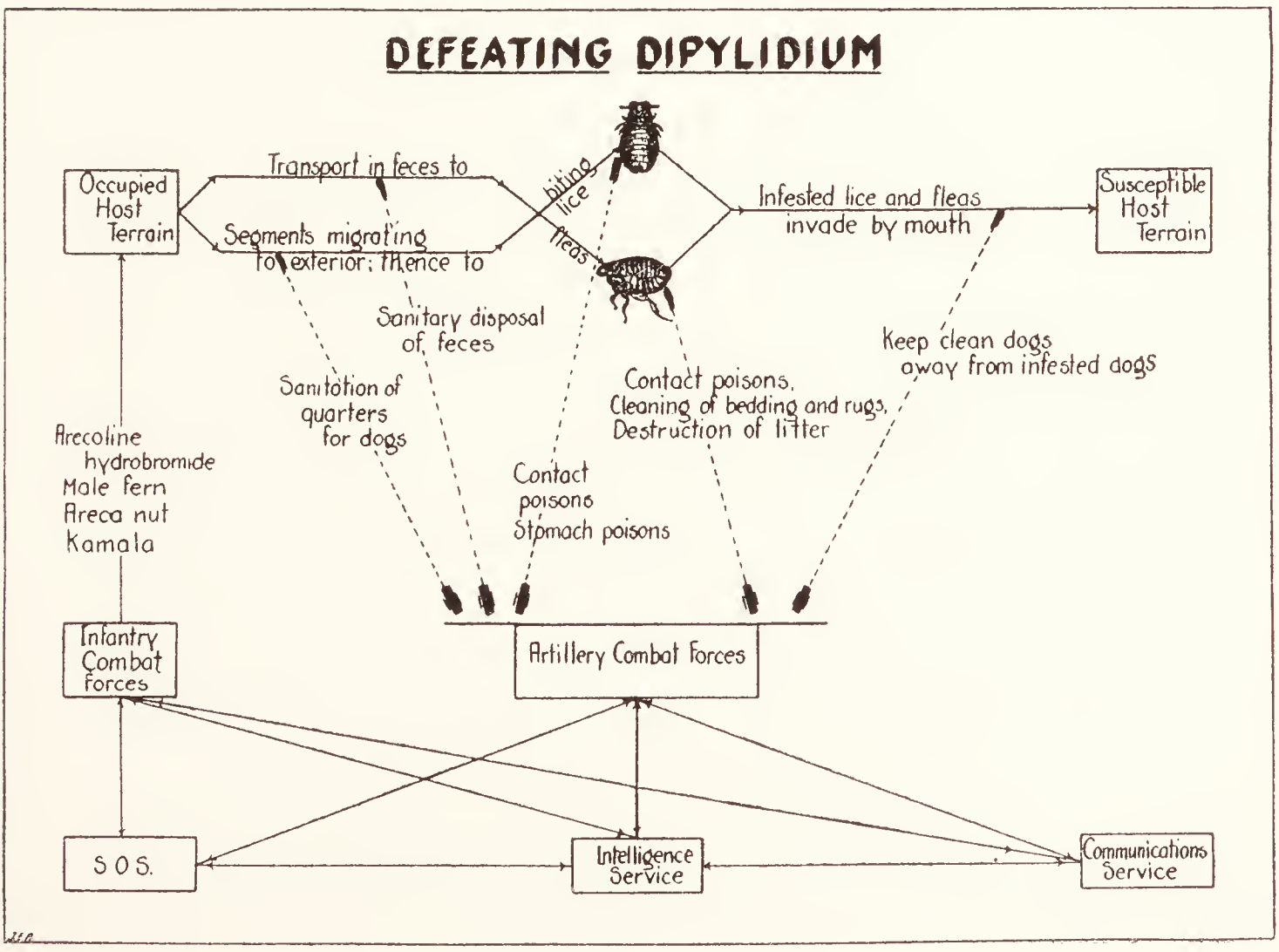
Dipylidium, on the other hand, depends for its transport on two forms of ectoparasites, fleas and lice. Its success in maintaining its effective forces and extending its range of captured and occupied territory depends largely on the maintenance of these lines of communication, and these in turn depend on the success of these ectoparasites in capturing, holding and extending their positions. Under the caption Fighting Dog Fleas, the position and prospects of the Dog Fleas are discussed. As regards the dog lice, it may be said briefly that we seem to be gaining ground against these enemies, and that there is a fair prospect of their ultimate destruction and eradication within a reasonable period of time.

Dipylidium occupies the lumen of the small intestine, holding its position by attaching to the mucosa by means of a head well armed with hooks and suckers; often this head burrows deep into and along the mucosa. Gravid segments filled with eggs in egg

capsules form at the end of the strobila opposite the head, and these segments detach, singly or in chains, and move out in feces or independently by migration through the anus. The next move depends on the ectoparasite used for further transport.

The skin of a dog may become soiled from contact with feces or tapeworm segments, thereby bringing the tapeworm eggs and egg capsules onto the skin. Biting lice feeding on the epithelium of the soiled skin swallow the eggs or egg capsules, and the eggs hatch in the lice and develop in the host's body cavity to cysticercoids infective for dogs. When dogs are annoyed by the bites of such lice and proceed to root them out of their hair and swallow them, the cysticercoids develop to adult tapeworms in the lumen of the intestine.

When the bedding or soil in which dog fleas are developing is soiled with dog feces, or when segments crawling from the anus of a dog fall into bedding or on soil in which dog fleas are developing, the larval fleas, which feed on organic matter, swallow the eggs in the feces or those released as the segments disintegrate. The eggs hatch in the flea larva and undergo partial development. After pupation the adult flea emerges, and at this time the tape-



worm cysticercoid completes its development to the infective stage. When such infested fleas annoy a dog and are rooted out and swallowed, the cysticercoid develops to an adult tapeworm in the small intestine of the dog.

For our infantry attack on Dipylidium we have effective weapons in the form of arecoline hydrobromide, male fern, freshly ground areca nut, and kamala. However, it is not so easy to destroy and drive out this tapeworm as it is to destroy and drive out the other dog tapeworms. Some of our attacks fail of complete success because the head of Dipylidium may be so deeply imbedded in the mucosa as to be out of range of the anthelmintic weapon used. In such cases the attack must be renewed as often as necessary until the enemy is dislodged and driven from its dugouts in the mucosa.

As artillery weapons we must use sanitation, especially the sanitary disposal of feces, to cut the enemy lines of communication by feces. Our most effective attack probably lies in destroying the fleas and lice which serve as transports for the enemy forces. Our mode of attack on fleas is discussed under the heading Fighting Dog Fleas. Our attack on biting lice can be conducted by the use of either stomach poisons or contact poisons. Sodium fluoride, in amounts as small as 1 gram distributed through the hair coat of a dog, will destroy biting lice; the dog must not be allowed to lick this irritant poison, and the hair coat should be kept dry until the dog can be thoroughly washed a few days later. Such contact insecticides as derris, pyrethrum powder coal-tar dips, and bland oils, if properly used, will destroy biting lice.

Probably the greatest practical difficulty in combating Dipylidium by an attack on its insect transport, is the difficulty in keeping clean dogs away from infested dogs. The social habits of dogs bring them into contact with all sorts of dogs whenever such contacts are possible, and from such contacts they commonly come away with a fresh supply of fleas and lice. Strict control of a dog's habits and movement is necessary to prevent such developments.

Our estimate of the situation is that we are in a position to destroy the forces of Dipylidium whenever it is possible to use our present weapons on a sufficiently large scale, including the

ability to establish control of the dog which now ranges without control. The dog not under control is probably the greatest problem in the control of dog parasites in general.

Fighting Dog Fleas

Over most of the United States, and especially in the East, the most common flea found on dogs and man is the common dog flea, *Ctenocephalus canis;* on the West Coast the most common flea on these hosts is the human flea, *Pulex irritans.* What is said here in regard to Dog Fleas applies specifically to the common dog flea, but applies, to a large extent, to the human flea also.

The Dog Fleas occupy the hair coat of dogs, moving actively about, and sometimes stopping at various places to requisition food in the form of blood. They move from an occupied terrain to a new terrain in one or two ways. (1) When a new terrain comes in proximity to an occupied terrain (for, contrary to conditions in human warfare, our parasite warfare is complicated by the fact that not only do friendly and enemy forces move from place to place, but also the terrains of actual or potential warfare move from place to place), the enemy forces move by leaps, often of astounding length, to the new terrain and secure positions on the new canine or human host. (2) Female fleas deposit eggs in the hair coat of dogs, and these eggs slip off and land on soil, or rugs, or in bedding in areas used by the dogs. Under favorable conditions the eggs hatch, giving rise to larvae which feed on organic debris, which debris, as noted elsewhere, may include fecal material containing eggs of Dipylidium. In due time the larvae form pupae, and from these pupae emerge the adult enemy forces, now ready to invade the first host terrain which is accessible to them.

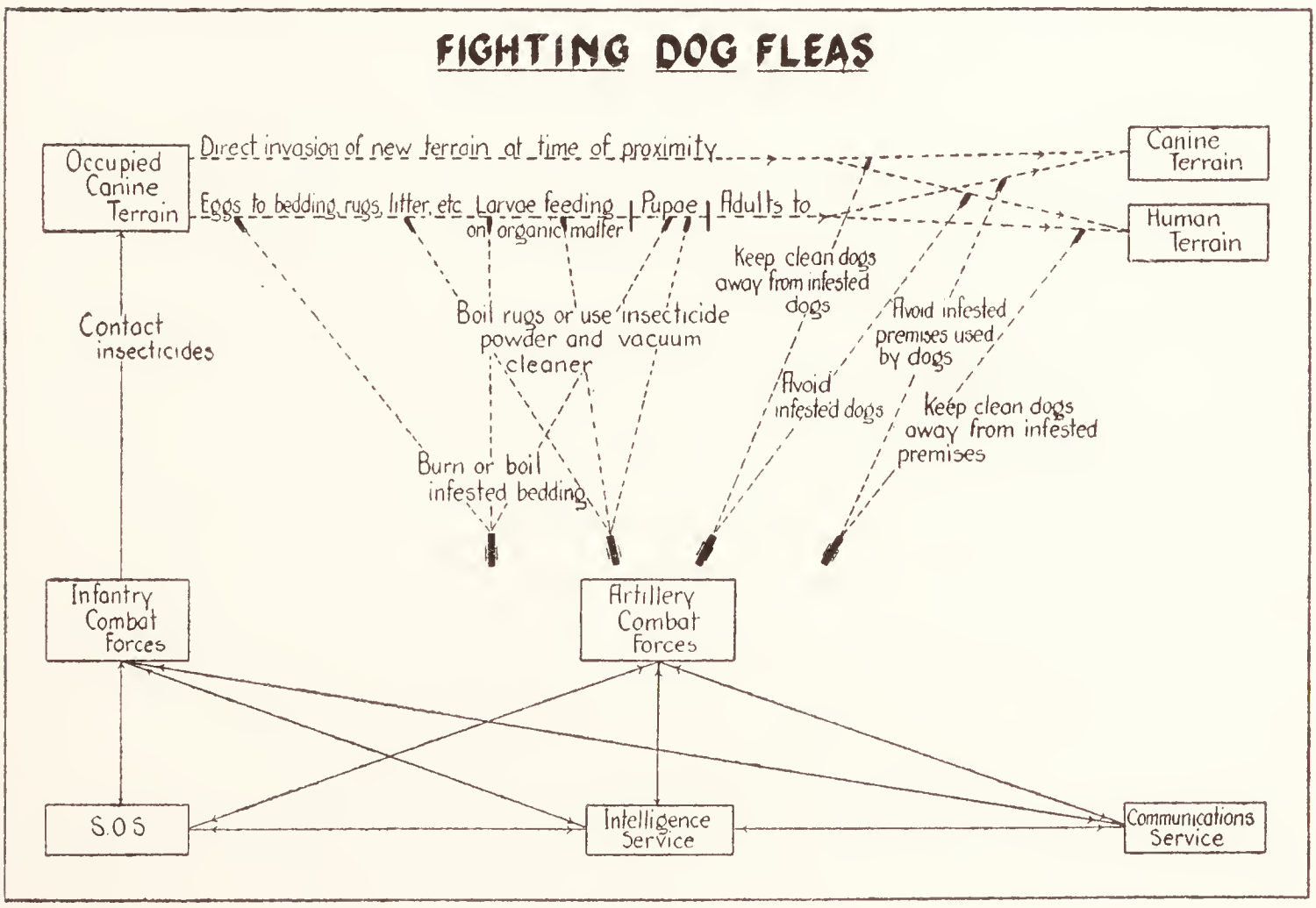
Against the adult enemy forces our Infantry Combat Forces have adequate weapons in the form of contact insecticides, such as coal-tar creosote solution, derris, pyrethrum, or powdered naphthalene. The attack with these weapons must be followed up by the artillery attack on reserves and lines of communication, or enemy reinvasion may be expected to follow very promptly and certainly. Indecisive battles are of little value to strategy.

The reserves of eggs, larvae and pupae can be destroyed by burning the bedding, litter and trash occupied by them, and cleaning up the kennels and runs with hot strong creosote oil containing from 10 to 16 per cent of tar acids. Pyrethrum powder or powdered naphthalene may be used to destroy these re-

serves in carpets and rugs or, whenever possible, carpets and rugs may be boiled. The constant use of a vacuum cleaner keeps down enemy forces in carpets and rugs.

Invasion as a result of proximity to occupied host terrain can be prevented by keeping clean dogs away from contact with infested dogs, and by human beings avoiding such contacts with infested dogs except as veterinary combat forces must wage war on the occupied terrains; their risks are in line of duty and are necessary in warfare. Invasion as a result of entering infested premises can be prevented by keeping clean dogs out of such areas and keeping persons out of them except as veterinarians or others may enter them for the purpose of destroying enemy reserves.

Under strictly civilized conditions, the complete destruction of the Dog Fleas is possible and is uncomplicated by unsolved problems essential to success. However, our civilization has numerous flaws, and the presence of the uncontrolled dog, as noted elsewhere, is one of those flaws. The uncontrolled dog will be the most difficult problem in carrying out a successful campaign for the eradication of the Dog Fleas.



Fighting the Cruel Heartworm

The Heart Worm moves from an occupied canine host terrain to an unoccupied terrain by mosquito transport; the Intelligence Service is still examining the possibility that it uses tick, flea or louse transport also. To cut this line of communication calls for the use of mosquito-proof kennels with self-closing doors, to cut the enemy lines from the occupied terrain to the mosquito transport and from the mosquito transport to the unoccupied terrain; for the destruction of the depots of this transport service (the mosquito breeding places); and for direct destruction of the transports by mosquito destruction. The first weapon is serviceable only as a locally useful bit of armament on a limited sector. The last two weapons are powerful and effective—but are little used. Much is written and said about destruction of mosquitoes and their breeding places, and relatively little is done.

In 1930 we had no effective infantry weapon for our attack on the enemy in an occupied terrain. Since that date the Intelligence Service has developed an effective weapon in the form of Fouadin (later Fuadin), an antimony compound. When brought into action, this weapon destroys first the reserve battalions of microfilariae in the blood and terminates the recruiting of new reserves by sterilizing the adult females; later it destroys the adult enemy forces gradually.

The enemy has been extending its lines over the United States very rapidly of late years. Long confined to the South, it has moved by speedy modern transportation north to New York, New Jersey and Pennsylvania, and northwest to Illinois. Dog owners as yet have given it little attention, and veterinarians, as a rule, have not troubled themselves about it except in a few places.

The estimate of the present situation is:

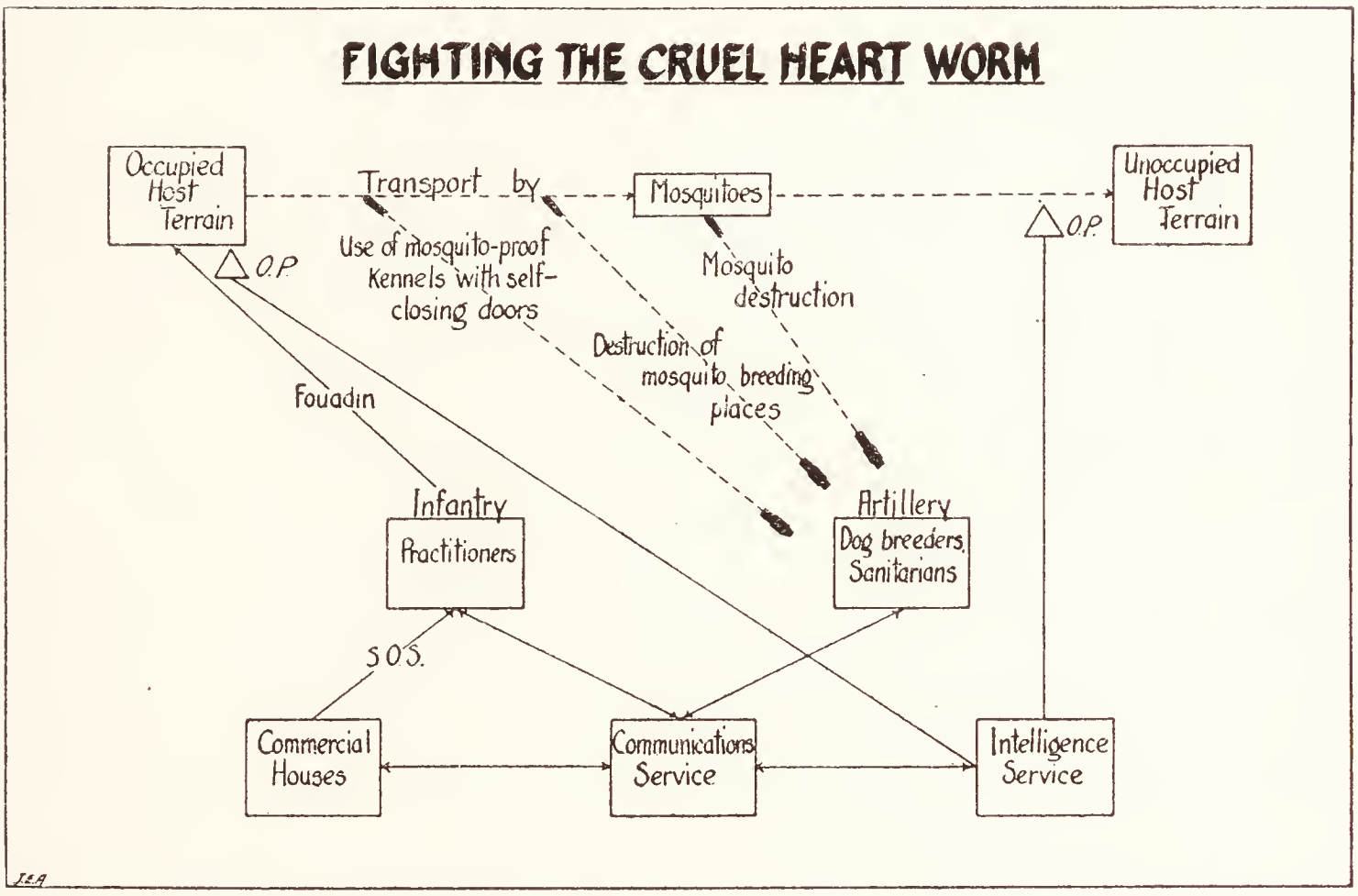
We have adequate weapons for a campaign against the Heart Worm—but we are not using them sufficiently to check the enemy advance.

The general public will not be greatly concerned or interested until the veterinary combat officers become concerned and interested to a much greater extent than they are at present.

A campaign against mosquitoes is justified not only on that one

score alone, but because it is also a campaign against the Heart Worm, Malarial Parasites and various other enemies. It is a conservation measure of value in draining and reclaiming land, protecting health, protecting investment in hotels and summer resorts, and in other ways.

The Heart Worm forces can be driven back and destroyed with existing weapons, tactics and strategy whenever we care to use these things effectively against those forces.



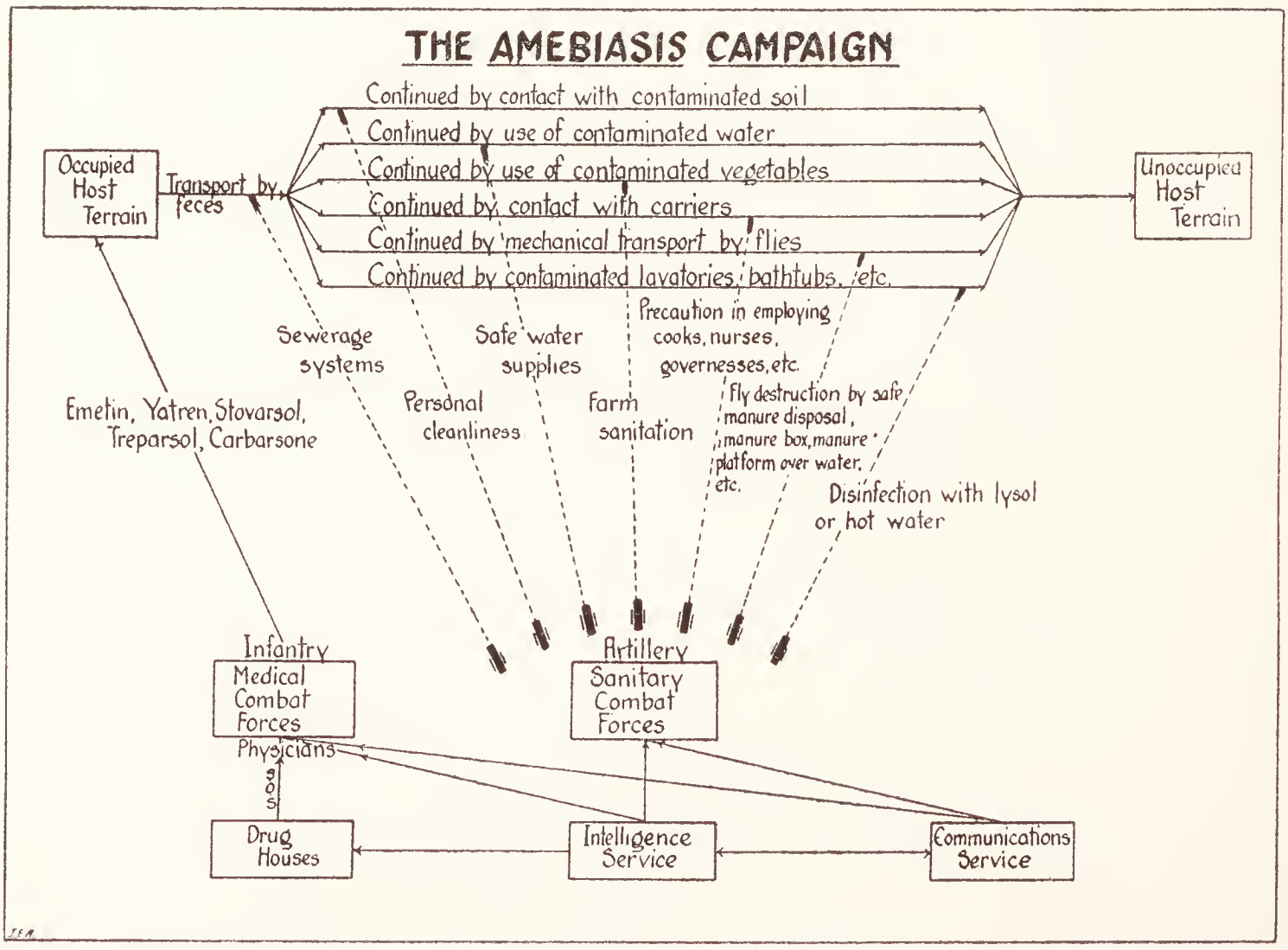
The Amebiasis Campaign

In connection with the accompanying diagram, the following points may be noted:

The Ameba moves by feces transport over a large network of lines of communication to the attack on man. To guard against so many different lines of attack is very difficult; it is even difficult to carry in mind the maneuvers necessary to prevent surprise attacks which are carried out with the greatest secrecy. Against this enemy we have much artillery—almost all of too small caliber to cut effectively the enemy lines of transport.

Following a successful attack by the enemy, we can counter-attack with an assortment of effective weapons which increase in number and effectiveness almost every year. If the counter-attack is begun in time it is usually successful; if delayed it may not be.

On various bases, our best informed officers have estimated that approximately 10 per cent of the people of the United States



are attacked by this enemy. In the large majority of cases there is little evidence of damage to the host terrain, but in a minority—a large number in the aggregate—the host terrain is seriously injured or destroyed.

An estimate of the situation would be as follows:

We are not gaining ground against the Ameba, but we are becoming better prepared to wage war. We need a more far-flung organization, better organized than are the present scattered units, and we need general officers to supply effective tactics and strategy, and with authority to wage war effectively.

The Campaign Against the Pinworm

Ordinarily an invaded terrain can be recaptured from a helminth enemy by one attack if we have suitable anthelmintic weapons, and can be held against counter-attack by means of our generally used sanitary weapons and defenses. In the case of the Pinworm, a battle is ordinarily insufficient, and the defeat of the Pinworm requires a campaign which may drag along for months or years and in which special artillery weapons must be kept in action to cut the unusual lines of communication used by this enemy.

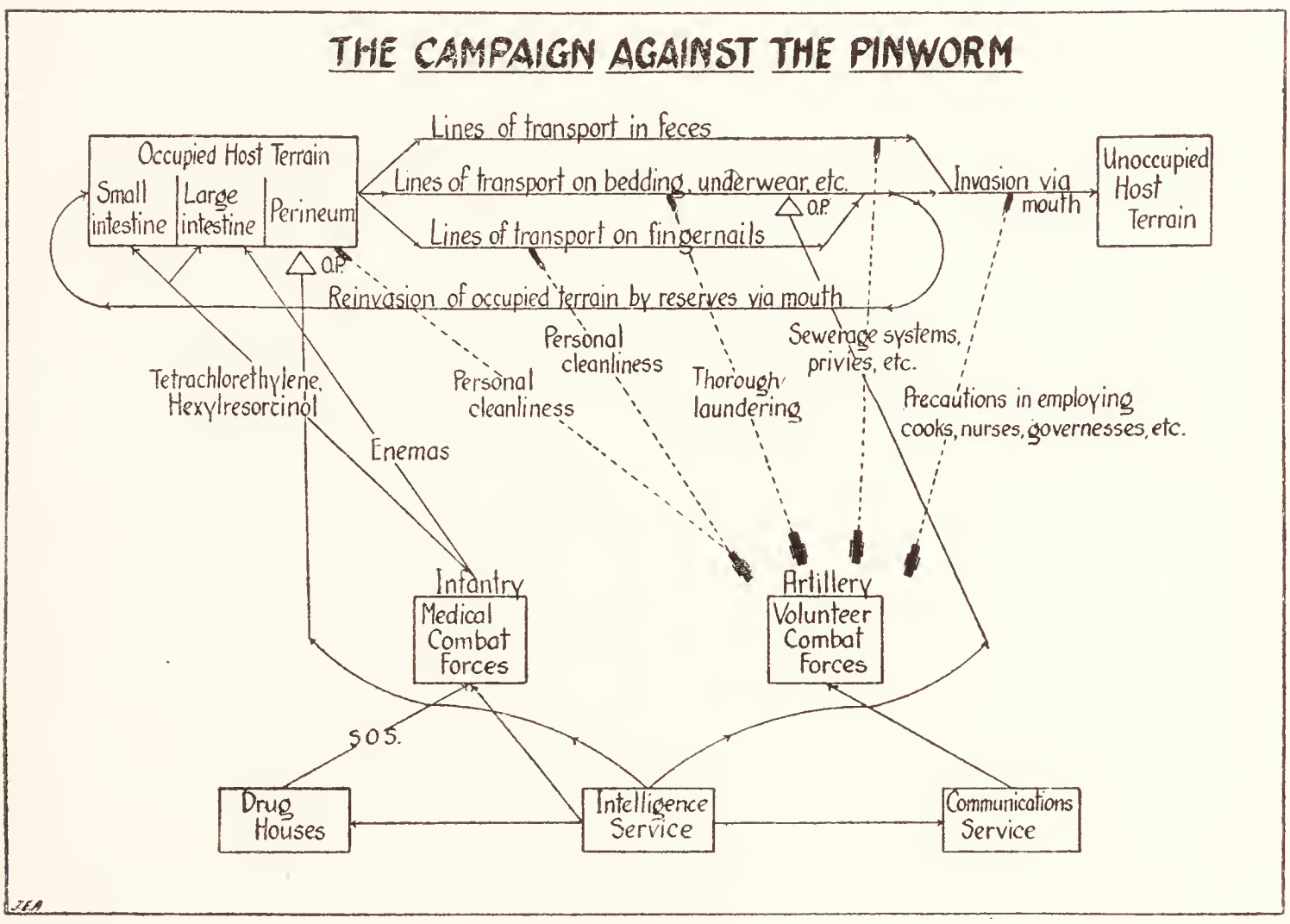
Our infantry weapons for direct attack on the parasite in the occupied terrain have not had adequate critical test to establish their true value. The method of testing by egg counts before and after treatment is not applicable in this case, and the technic which would be applicable has not been followed. Tetrachlorethylene is evidently a valuable weapon, even though its precise value is unknown. Its safety has been well established, and Hall and Augustine have reported the destruction of 5544 Pinworms with a 4-cc. dose of this drug, an indicated destruction of 90 Pinworms by each minium of the drug. Brown has reported that hexylresorcinol is very effective in destroying Pinworms, and the drug is regarded by Lamson, Brown and others as very safe. Further tests should be made to show what proportion of these enemies are left uninjured by an attack with either of these weapons.

The females of the enemy forces do not deposit eggs which pass in the host's feces, although some females pass in the feces or are crushed by the anal sphincter. Usually the females, when full of eggs, migrate through the anus to the perineum, and deposit their eggs here. Here the eggs become infective, and cause a pruritus leading to scratching of the itching region. By means of this scratching, worm eggs get under the fingernails or on the night clothing, underwear or bedding, and thus back to the patient and to others associated with the patient.

Our sanitary weapons in the form of sewerage systems and privies cut these lines of communication in rare instances only, and this enemy commonly breaks through our sanitary barrage

and invades even the best social groups, ranging from the polar region through the tropics. The weapons of great personal cleanliness, thorough laundering, and precautions in employing cooks, nurses, governesses, waiters and others, must be used as extensively as possible.

As a basis for a sound campaign against Pinworms, the Intelligence Service should provide us more information as to enemy habits and as to the effectiveness of our weapons. When this is done we shall be in a better position to fight effectively.

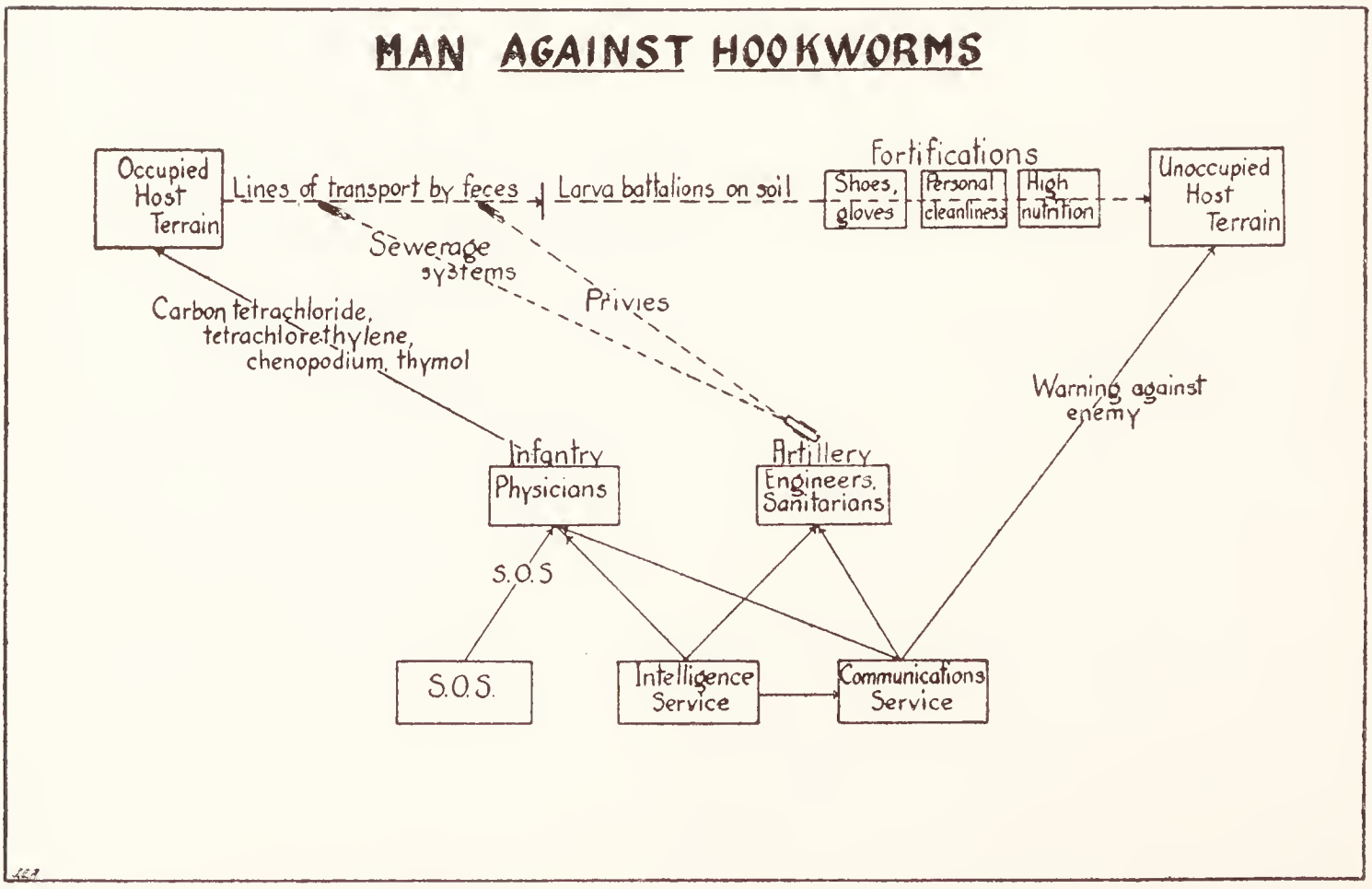


Man Against Hookworms

The Hookworm enemies which attack man move from an occupied human terrain to an unoccupied human terrain over the line of transport by feces which is the line most commonly used by parasites. Their eggs develop into the reserve battalions of infective larvae on soil, and these attack man by way of the skin or by way of the mouth.

Against these enemies man can wage war to the point of annihilation of enemy forces, so far as effective weapons are concerned. Our infantry (the medical profession) is equipped with several quite effective weapons for the destruction of enemies in an occupied terrain. The heavy artillery of sanitation, the widely used and broadly useful sewerage system and privy, is effective in cutting the line of communication by transport in feces. Against individual attack in the danger zones where these sanitation weapons are not used, are the fortifications of shoes and gloves to prevent attack through the skin, and of personal cleanliness to prevent attack by skin or mouth.

A campaign with the complete destruction of the enemy as an objective is entirely practical, provided adequate personnel and

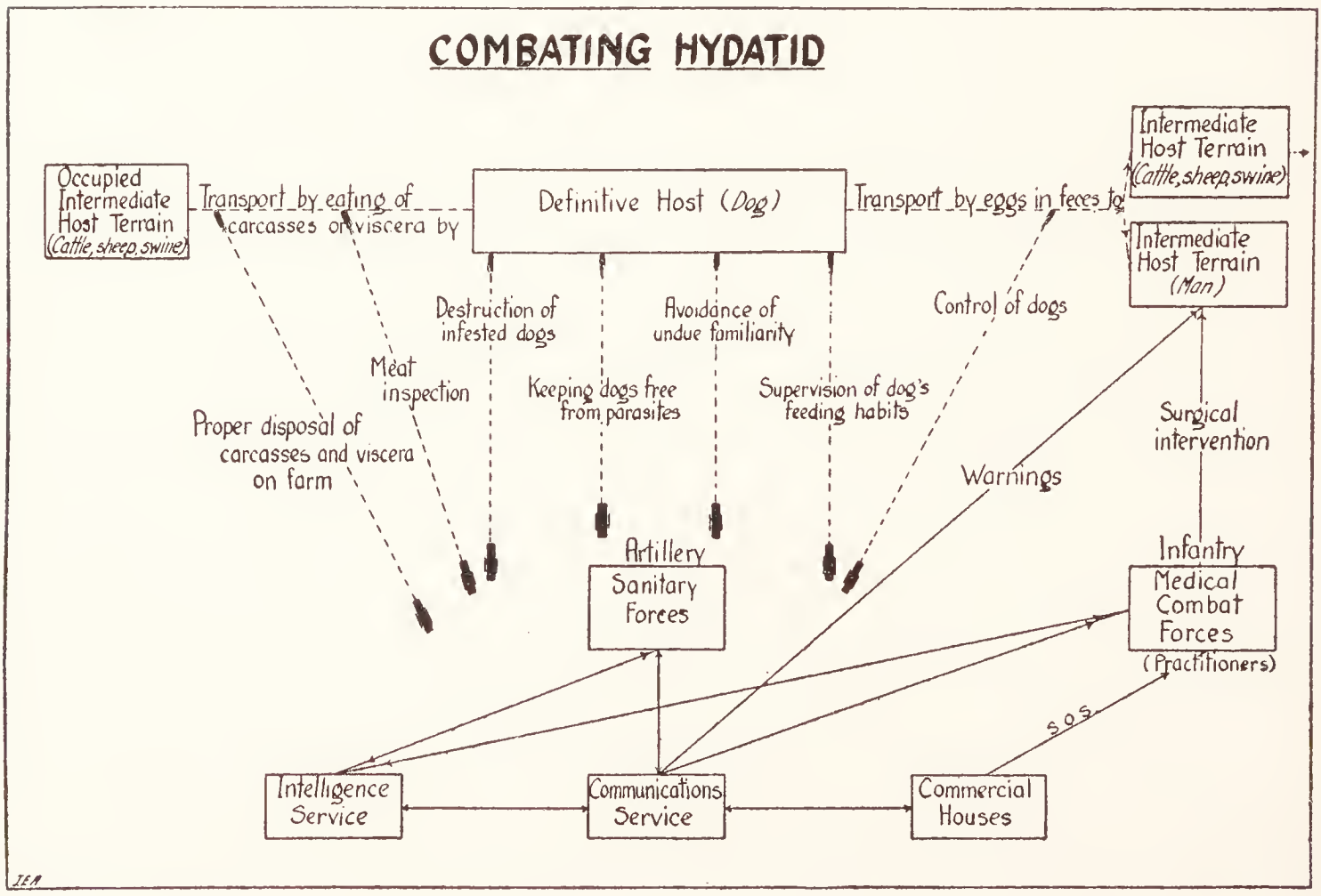


funds are available. Against this enemy man is making considerable headway over most of the world, and by virtue of definite campaigns and an increasing use of sanitary weapons the annihilation of the Hookworm enemy may be expected at a not remote future date.

Combating Hydatid

The Hydatid is an enemy that is capable of capturing almost any mammalian terrain and occupying almost any tissue in such a terrain. Because of its relatively large size, its capacity for rupture, and for other reasons, it is very destructive to the invaded tissues and to the host. In hosts other than man, the Hydatid may move to a dog when the dog eats infested carcasses or viscera, and in the dog, or some related carnivores, the hydatid scoleces may transform to very small adult tapeworms in the small intestine of the carnivore host. In man the Hydatid is in a terrain from which no lines of communication lead out, since the human dead are usually burned or deeply buried under the protection of coffins. The adult tapeworms in the dog produce eggs which pass in the feces, and thence in contaminated food or water, or as a result of too great familiarity with dogs, to a new terrain in man or other mammals.

Against this enemy we have adequate weapons, not all of them adequately used. The enemy lines of communication between the occupied terrain in cattle, sheep or swine (usually sheep in most countries; usually swine in the United States) and the dog



are readily cut by such weapons as the proper disposal of carcasses and viscera on the farm and adequate meat inspection in the slaughter houses. In the United States the more extensive and effective use of these weapons in the past 35 years has definitely driven back the Hydatid enemy over many fronts.

The dog terrain is better protected by increased and improved veterinary service in freeing dogs from parasites and keeping them more generally free from them. Dogs in general are more carefully supervised than formerly, and fewer of them are left to forage for a living. It is said, without precise confirmatory data, that we have adequate anthelmintic weapons for the destruction of this tapeworm in the dog, but except under unusual conditions the destruction of the occupied terrain and its enemy population would be indicated, since this enemy is too dangerous to man to warrant taking chances on any enemies escaping.

In general, we are gaining ground on this enemy. With a more general use of our available weapons, the complete destruction of the enemy forces may be expected.

The War on Livestock Parasites*

The control of parasites may be envisaged as a form of warfare, and hence as something to which the general terms of military tactics and strategy may be applied. This paper undertakes to present the subject from that point of view. It is proposed to present a representative and fairly comprehensive set of military problems in connection with our warfare on parasites, to take the information afforded by our intelligence service, and to apply that information to the solution of our problems, indicating the technical and strategic maneuvers developed by staffs of our services for the combat forces of the practicing veterinarians on the firing line.

We proceed, first of all, to a consideration of the enemy forces, since our tactics and strategy will vary in all cases with the nature of the enemy we confront. We have the great advantage of being able to select and vary our plans of campaign, whereas our enemies have the disadvantage of having to follow a planned campaign with but little possible variation. These enemy forces are vast in number and are comprised of unit groups much more varied even than those of the modern army with its infantry, field and heavy artillery, tank corps, machine gunners, aviation service, and chemical warfare sections. The enemy forces include hundreds of species of parasites, ranging from the microscopic Protozoa through the worms and up to the insects and mites, and their weapons, maneuvers and modes of attack vary correspondingly.

Some of these enemies attack with biting mouth parts, some with poisons, some with pressure brought to bear on host tissues, and some in other fashions. Mosquitoes, lice, fleas, mites and ticks attack the skin and either puncture it and suck blood or serum, or chew off the superficial epidermis. Anaplasma and Piroplasma invade the red cells of the blood and cause destructive and toxic effects. Hookworms, Strongyloides and certain fluke larvae penetrate the skin and wander through the tissues. Ascarids and swine kidney worms in their larval stages penetrate the walls of the intestine and wander through the body. Larval tapeworms wander through the body and develop in tissues, in

*Reprinted by permission from the Cornell Veterinarian, Vol. XXII, No. 4, Oct. 1932.

many cases causing pressure atrophy. Our enemies use many weapons and many of these weapons are very destructive.

The mode of invasion of host animals varies with different parasites. The aviation corps of mosquitoes, biting flies, and biting bugs swoop down on our animals, wound them, despoil them of their blood, and fly away. Some mosquitoes in the Tropics carry bombs in the form of eggs of Dermatobia. Seed ticks lie in ambush in tall vegetation, and attack our animals as they go by. The mites are sappers that dig tunnels in the skins of animals, working their way from time to time to new hosts that come in contact with older hosts where these mites have a foothold. Ascarids produce enormous numbers of eggs, and while some of these perish, the sheer size of the total ensures their getting back to some of their hosts in contaminated food and water; enormous egg production is one of the favored forms of enemy tactics for securing "superiority of fire" over the battlefields of the pasture, field and pen.

Advancing to the attack through food and water is a common line of strategy used by nematodes, tapeworms and flukes, and is not always a matter of mere contamination of food. A more subtle variation of these stratagems consists in entering our livestock in the form of larval parasites within the animals which are customarily or accidentally eaten by our domesticated animals. This strategy is somewhat akin to that of the Greeks in taking Troy by means of the wooden horse, the enemy lying concealed within a gift. Thus a tapeworm embryo may develop to a bladderworm in a rabbit, and become an adult tapeworm in a dog when a dog eats the rabbit. Certain chicken tapeworms develop to bladderworms in beetles, earthworms or other invertebrates, and develop to adult tapeworms in chickens when chickens eat these parasitized invertebrates. Of this parasite set-up, as of the Greeks and their horse, it may be said: *"Timeo Danaos et dona ferentes."* Even the fact that sheep and cows in grazing will accidentally swallow fairly large numbers of beetles and similar things, is taken advantage of by certain nematodes, such as Gongylonema, which develops as a larva in these beetles, and develops to an adult worm when sheep and cattle swallow these infested intermediate hosts.

Finally we have the double or triple invasion in which an aerial attack by mosquitoes simultaneously lands an infantry

force of Plasmodium or filarid worms on the shores represented by the skin of a host, and this landing party penetrates into the interior, settles down and the descendants of the original landing party occupy much or most of the territory. A tick may simultaneously land the forces of Piroplasma and Anaplasma on our bovine friends.

To combat these enemies we must first of all have certain information about them, and to secure that information we have two military services, the intelligence service of the research laboratory, organized to study the identity, weapons and modes of warfare of our enemies, and the service of the diagnostician, the man versed in the art and science of diagnosis as developed for the purpose of identifying the enemy forces along the combat sector where the practicing veterinarian is engaged.

The identification of enemy forces involves this dull business of taxonomy, the identification and classification of parasites, of which we hear so much complaint. We complain, but we do not think clearly when we damn these Latin scientific names. They are the very heart of diagnosis and therapeutics in dealing with parasitism. They identify the pictures in our "rogues gallery" and the finger prints of our parasitic enemies. If we know the name of our parasitic enemy, we know, in effect, his regiment, and if the intelligence service has investigated this regiment adequately, we know the nature of its orders to attack, when and how it will attack, how it is armed, where its forces are disposed, against which weapons it is vulnerable, and how it has behaved in previous campaigns when confronted with certain tactics. If there is any error in this business of identification, all our tactics may go for naught. We know that the weapons and tactics which are effective against a White Army may not be effective against a Green Army, and if we attack the Green Army with the weapons effective against the White, under the impression that we are facing a White Army, the Green Army will win and we and our livestock will lose. It is worth recalling in this connection that taxonomy and tactics are derived from the same Greek root.

It is, therefore, of the utmost importance that our intelligence service spy on the hostile forces, and furnish to our combat forces precise information as to the nature of each hostile unit, and the exact marks of identification whereby our combat forces

may recognize the enemy which confronts them, and readily learn what is known about the force operating under the name which, for purposes of identification, we attach to these enemies.

Similarly, it is essential that our combat forces be supplied with diagnosticians who serve as scouts in applying the information afforded by the intelligence service, and in ascertaining in any given sector of the war with parasites just which of the enemy forces is engaged. These scouts must be skillful in following trails, reading enemy signs, and drawing sound conclusions from the information they acquire. Clinical observations, somewhat like the observations from captive balloons, afford evidence from enemy activities that the opposing forces are probably protozoan, worm or arthropod forces. Raiding parties are sent out to capture enemies in scrapings, blood smears, fecal samples or other things, and these captives are questioned by the intelligence service to ascertain the exact regiment to which they belong. When all these observations are put together, they may be correlated with the other information already ascertained in regard to the activities of that regiment, and with what is known as to its inability to withstand attack with certain weapons, as to how its lines of communication may be cut, or as to what enemy allies may be defeated and the war brought to a victorious conclusion.

When these procedures have been carried out, the combat troops of the practicing veterinarians call on the service of supplies and the ordnance service for equipment and weapons. These services are the services of therapeutics and surgery and of the commercial houses supply instruments, drugs, chemicals and biologics. The use of our anthelmintic and insecticide weapons is a phase of tactics with which I have dealt in many papers, and in this paper emphasis is laid on other tactics and on general strategy.

When equipped, the combat service makes its attack. The enemy forces are entrenched in or on the friendly terrain of our allies, the domesticated animals. Our weapons must be selected with the thought that they must destroy parasites or such of their allies as intermediate hosts, without great injury to our allies. Here the combat forces must exercise their knowledge of tactics and strategy, as bad judgment may result in the destruction of our allies, or in other ways give victory to the enemy and inflict defeat on us.

The training camps of the veterinary schools should supply basic instruction for our combat forces, but it is still true that "We learn by doing," and the practitioner of long standing and experience should show the superiority which attaches to veterans. Experience is the one great advantage of age over youth. A study of the world's wars and battles for thousands of years, indicates that, as a rule, military men with years of theoretical training habitually find that the application of theory to actual warfare is precisely as difficult as the application of theory in general to practice in general, and because of this the story of wars and battles is, for the most part, the story of generals on both sides making one mistake after another, frequently ancient and well-known tactical blunders, until one of them makes a fatal mistake, and the other general wins by virtue of his opponent's errors rather than virtue of his own ability. Exceptionally, an Alexander the Great, a Hannibal, a Caesar, a Tamerlane, a Genghis Khan, or a Napoleon gives evidence that he has innate military ability superior to the innate or acquired abilities of his enemies, but these are cases of genius of a military sort somewhat comparable to that of musical and mathematical prodigies. Consequently it is to be expected that experience in veterinary medicine will be an outstanding asset in practice. Fortunately, we can carry on our justifiable warfare against parasites constantly and acquire proficiency by practice; equally fortunately, our less justifiable warfares of man against man are more sporadic, and unless the world goes insane and indulges in perpetual human warfare our military men will continue to have comparatively little opportunity to acquire proficiency in the art of human slaughter.

Our attack on parasites takes the form of an offensive, treatment, and a defensive, prophylaxis. In either case the combat forces must take into consideration the facts about the habits of the enemy forces which have been ascertained by the intelligence service.

Treatment may be surgical, as in removing the gid parasite from the brain of a sheep, or by the application of drugs externally or internally, as in the use of insecticides or anthelmintics. The selection of weapons will vary with the enemy to be attacked. The external parasites may be localized, as in the ear of a rabbit, dog or cow, and a local attack will eliminate

them, or they may be present over a wide battle front, as on the hide of a dog or cow, and a general enveloping attack with the weapon of the dipping vat is necessary. If they have dug in, as do various mites, successive waves of attack must go over the top at suitable intervals, storming the outlying fortifications and mopping up in the dugouts. The attack with anthelmintics must be timed, in some cases, to await invading forces wandering through the tissues of our domesticated animals and out of range of our guns; such forces must be cut off from reinforcements by sanitation or other means, and allowed to take up positions in the trenches where they may be brought under fire. The anthelmintic attack must often be followed by a mopping-up party in the form of a purgative, or accompanied by a purgative to pursue the fleeing enemy or protect the friendly terrain.

While there is available material for compiling a Manual of Tactics and Strategy for the war on parasites, this information has not yet been synopsized in the compact form in which it might be presented, and an attempt to compile it will not be attempted here. Our therapeutic procedures will be listed as our offensive arms, and our prophylactic procedures as our defensive arms, but it will be noted that in some cases our defense partakes of the nature of an offensive, and it is an ancient military axiom that often the best defense is an offensive. Thus our attacks with anthelmintics and insecticides cut off enemy reinforcements at their source.

To formulate our list of offensive and defensive arms it is first of all necessary to group our enemy forces in accordance with their customary tactics and strategy. The tactics and strategies will cover many variations, and every variation has a bearing on our attacks. We take the following grouping on the basis of parasite habits, to show the variations in our problems and in our solutions of these problems.

Arthropod Parasites, Usually External

Group 1. Mosquitoes, biting flies, etc. Occasional parasites as adults (feeding from time to time, but otherwise free-living); breeding off host.

Offensive weapons: Of limited value against adults. Attack centers on larva in breeding places (i. e., use of oil to destroy mosquito larvae in water).

Defensive weapons: Of temporary and limited value (i. e., use of repellents, smudges, screens, etc.).

Group 2. Lice, mites, etc. Permanent parasites in all stages except egg (remaining on hosts; feeding more or less constantly, or intermittently); eggs laid on host.

Offensive weapons: Insecticides, best used in dipping vat to ensure that attack ranges over all territory that could possibly be occupied; since weapons used are not effective against parasite eggs, a second attack should be made by a mopping-up party, and timed to allow for the hatching of all eggs present at time of first attack, but before any new hatch can lay eggs; if enemy has dug in (scab mites), repeat attacks at suitable intervals until all enemy dug-outs have been cleared out.

Defensive weapons: Cut the enemy lines of communication by keeping uninfected animals away from infected animals and areas occupied by them.

Group 3. Ticks and fleas. Permanent parasites as adults, and sometimes in larval or nymphal stages; eggs not laid on hosts.

Offensive weapons: Insecticides, best used in dipping vat, the attack to be repeated as often as enemy invasion occurs.

Against ticks, pasture rotation systems may be used to starve the enemy to death, but this form of guerilla warfare does not lead to decisive victory as rapidly or dependably as a widespread offensive with the heavy artillery of the dipping vat.

For destruction of fleas, the destruction of the reserve forces of eggs and larvae in bedding and other breeding places is essential, and failure to destroy these reserves will be followed by the movement of these reserves into the front-line trenches as effective combat troops.

Defensive weapons: Post a quarantine guard to keep tick enemies out of unoccupied areas; in all cases cut lines of communication over which enemy forces might travel from occupied to unoccupied areas.

Group 4. Bots, ox warbles, etc. Permanent parasites as larvae; eggs usually laid on hosts; adults free-living; larvae wander in host tissues.

Offensive weapons: Attack larvae *in situ* when accessible, i. e., bots when they have reached the stomach, warbles when they have reached the back, etc.; attack bots with insecticide (carbon

disulphide); attack warbles with traumatic weapons (squeezing, removal by forceps, etc.) or insecticides (derris, etc.). Destroy bot eggs with cresol solution.

Defensive weapons: Large-scale campaigns to clear enemy out of extensive geographic areas, thereby making penetration back into these areas difficult by virtue of distance to be covered; use of nose-guards against nose fly to prevent enemy activity in egg-laying area; use of sheds to establish unfavorable area for maneuver of bot enemy.

Worm and Protozoan Parasites, Internal

Group 1. Trichuris, Ascarida, Heterakis. In lumen of digestive tract; eggs pass in manure; no intermediate hosts; eggs return to hosts as infective eggs; larvae do not wander or invade tissues so deeply as to be entirely out of range of anthelmintic weapons.

Offensive weapons: Anthelmintics selected for known efficacy are available against many of the enemies in this group; attacks most effective against those in small intestine; repeated attacks necessary against those in ceca, since much of our attack spends its force before reaching the ileo-cecal valve, and part of the attack will pass the ileo-cecal valve and fail to penetrate the occupied territory. Apparently not necessary to time attack with reference to allowing tissue-invading larvae to return to lumen of digestive tract, as invasion is usually not very deep or apparently out of range of anthelmintic weapons.

Defensive weapons: For all cases where eggs or larvae pass in manure, including this group and groups 2 to 9, inclusive, and 11, 12, 14, 15, and 19, the following general strategy is applicable: Since the recruits for future armies of enemies are assembled in the manure, we have an outstanding opportunity to destroy these armies before they can even organize their forces, much less go into action, by a suitable disposal of this manure. This line of attack has been the most successful of all lines of attack on human parasites, and with few exceptions our sewerage systems for the disposal of human excreta have served to destroy parasite enemies of man. It is impossible to apply this form of tactics to parasite enemies of livestock to anything like the same extent, but we have not yet utilized these tactics to the extent that they are useful.

It is especially difficult to deal with manure scattered over

wide spaces, such as pastures, since we do not have the chance to deal with accumulated material, but even here something may be done. In dealing with such valuable animals as Thoroughbreds, it has been found practical in some cases to shovel up the manure on the pastures daily and cart it away. Anything which will expose the manure to the lethal action of sunlight, heat and drying will aid in destroying the relatively unresisting enemy forces in the form of eggs and first- and second-stage larvae, and for this purpose drags may be used or chickens will serve to scatter manure.

When the manure is in accumulated form, as when it is removed from stables, barns, hen-houses and similar structures, it can be handled in even a more effective manner. The use of the manure box with a double wall, and with the space between the sides of the double wall packed with an insulating material, such as sawdust, is highly effective in destroying our worm enemies, as the self-heating of manure in such boxes results in temperatures as high as 170° F., and this heat destroys almost all enemy forces in the course of a week or two. This procedure is effective against all enemies utilizing manure for conveying new invading forces to the outside world, and its effectiveness is independent of all subsequent developments, such as the use or non-use of intermediate hosts, or other considerations. The diagram indicates the tactical value of this form of attack.

Pasture rotation and stock rotation on pasture are valuable strategic measures in circumventing parasites and leaving them to perish, but their usefulness is limited in some ways. Certain enemy forces will occupy pastures longer than the pastures can be left unused. If the enemy utilizes intermediate hosts, especially hosts which travel considerable distances, as do beetles and similar things, rotation systems do not serve to cut their lines of communication.

Plowing under of pastures, whenever practicable, doubtless serves to dispose effectively of many enemies, but does not dispose of all of them to advantage, even if forage crops are sown. Moreover, there are advantages in the permanent pasture, aside from its danger from parasites, and it is not always advisable to plow pastures. Against this group 1, and against group 2 of our enemies, plowing under of manure is decidedly advantageous, as noted under group 2.

Light stocking is a strategic measure which serves to dispose our allied forces in such a way that enemy attacks cannot be carried out with a high concentration of effectives, thus leaving our allies to deal with relatively small skirmishing parties against which the weapons of immunity may be invoked, often with considerable success.

Group 2. Ascaris and related forms. Same as 1, except that larvae do wander out of range of anthelmintic weapons.

Offensive weapons: As for 1, except that if it is hoped to exterminate the enemy with one attack, it is necessary to protect the host animals against new invasions previous to treatment for the time necessary to allow wandering enemy forces to return to the lumen of the digestive tract before bringing the terrain under fire; in default of this procedure, it is necessary to throw sanitary defenses around the host after the first treatment, to allow wandering forces to come within line of fire, and then send over a second attack. If no consideration is given to the possible existence of wandering enemy forces, decisive victory is not likely to follow our attacks, and continuous warfare takes the place of decisive combat.

Defensive weapons: Against this group of parasites and against those in group 1, both of which produce eggs which pass in the manure and return to the host as infective eggs, manure disposal by burying or plowing under is much more effective than it is against enemy forces producing eggs which hatch and give rise to larvae on pasture, or which are eaten by intermediate hosts and develop to infective larvae. These eggs will stay buried, and will not crawl to the surface as larvae may do, and if eaten by invertebrates will not develop and perhaps get back to their hosts in these invertebrates.

Group 3. Haemonchus, Nematodirus, Ostertagia, Cooperia. In lumen of digestive tract; eggs pass in manure; no intermediate hosts; eggs hatch on pasture or soil, the young worms developing to infective third-stage larvae which are swallowed; larvae usually do not wander or invade tissues so deeply as to be out of range of our anthelmintic weapons.

Offensive weapons: Same as 1.

Defensive weapons: The essential features here are that these enemies produce eggs which pass out in the manure, but the enemy forces return to the attack as infective third-stage larvae and

not as eggs. This is true also of groups 3 to 6, inclusive, and of group 9. What is true of manure disposal in general, as discussed under group 1, is true here. In these cases, as noted above, there is, however, less likelihood that plowing under of manure will be effective, since the larvae may move upward to the surface of the soil. However, this is a point which has had comparatively little investigation by the intelligence service, and we are not sure of the effects of this form of strategy. In general, the disposal of stable manure on areas used by stock of a different sort, and hence capable of using the weapons of species immunity against the parasite enemies of different kinds of stock, is indicated, as is the disposal of manure at a distance from areas used by stock of any sort in order to cut the enemy lines of communication.

Group 4. Ancylostoma, Uncinaria. Same as 3, except that infective larvae may either be swallowed or may penetrate the skin; penetrating larvae wander, and swallowed larvae may or may not wander.

Offensive weapons: Same as for 2.

Defensive weapons: Same as for 3.

Group 5. Strongyloides. Same as 4, except that larvae first produced may or may not develop to free-living generation of adults, giving rise to infective larvae in any case.

Offensive weapons: Strategy same as 2, but weapons need further test before we shall be sure of our arms against Strongyloides; subject still under consideration by intelligence service.

Defensive weapons: Same as for 3.

Group 6. Strongylus, Oesophagostomum. Same as 3, except that larvae are swallowed and wander or penetrate tissues out of reach of our anthelmintic weapons.

Offensive weapons: Same as 2, but enemy wanderings are slower and longer, and time of return to places which can be brought under fire is not well ascertained by the intelligence service. Strongylus in the cecum of the horse is an exception to the general rule that enemies in the cecum are brought under fire with difficulty; this follows from the fact that the cecum of the horse has two openings, thus bringing that area in line of fire.

Defensive weapons: Same as for 3. Dalrymple has outlined a special plan of campaign against nodular worms in the bare-lot method, in which ewes and their lambs are kept on bare lots and

fed cut feed to prevent lambs from picking up infective larvae as they would on pasture.

Group 7. Dictyocaulus. In air passages of lungs; larvae pass in manure; no intermediate hosts; develop to third-stage larvae and are swallowed; larvae wander to lungs.

Offensive weapons: Not well established. In general, the defensive armor of the lungs of host animals is relatively less resistant to the incidental attack of our anthelmintic weapons, so far as these have been adequately tested, than is the defensive armor of the enemy cuticle to the direct attack of these weapons. The labyrinthine structure of the lungs and its drainage system of open tubes makes it difficult to lay a fire on enemy forces with liquid weapons, and the most promising line of attack would seem to be with gas; such a procedure requires the development of weapons not as yet adequately established.

Defensive weapons: Same as for 3. In this case, experience indicates that during an enemy attack our sheep allies usually suffer seriously for about 6 weeks, after which time their defensive immunity serves to protect the survivors. Relief work in supplying our allies with plenty of good nourishing food and clean water, coupled with cutting the enemy lines of communication by sanitary measures, such as isolating sheep in clean barns, usually serves to defeat the enemy.

Group 8. Synthetocaulus, Muellerius, Metastrongylus. Same as 7, except that intermediate hosts are used.

Offensive weapons: Same for 7.

Defensive weapons: The general measures outlined under 1, for manure disposal, apply here, but since in the special cases of Synthetocaulus and Muellerius, land snails are used as intermediate hosts, a special strategy is possible. Land snails can be detroyed by spraying the fields with copper sulphate solution. Moreover, since the deliberate eating of snails by sheep might follow from a mineral deficiency, the provisions of bonemeal, lime and salt in the feed, or in the form of a lick or mineral mixture, might serve to prevent the eating of these snails.

In addition to part of the general strategy applicable against all enemies with eggs or larvae passing in the manure, as discussed under 1, special measures may be taken to cut the enemy lines of communication through intermediate hosts other than snails. In the case of Metastrongylus, as in group 9, intermediate

hosts are earthworms. It is evident that plowing manure under is one of the lines of attack that should not be employed in this case, as such a move will only serve to effect a junction of enemy forces. It would be more logical to reverse this procedure by placing the manure on drying platforms where earthworms would not have access to it, but this is a measure which has not been tested out and would be applicable only when the enemy threat warranted the maneuver, as when valuable poultry was seriously threatened by the enemies of group 9, gapeworms. Measures to destroy earthworms might be taken, but at the present time this does not appear to be very practicable.

However, the intelligence service furnishes the information that the earthworms which furnish much the best terrain for enemy concentration and maneuver in the case of swine lungworms, are those which breed in manure and not those which breed on pastures. Consequently the classical strategy of the swine sanitation system finds another application here, since that system keeps our swine allies on clean pasture and out of filthy hog lots and pens where the dangerous earthworms are present, thus preventing a junction of enemy forces which is essential in the fixed plan of campaign of swine lungworms.

Group 9. Syngamus. Eggs pass in manure; become infective as eggs, or hatch and release infective larvae; intermediate hosts may or may not be used.

Offensive weapons: Traumatic; removal of enemies by hair or wire loops or similar weapons.

Defensive weapons: Syngamus has waged war on our turkeys for ages, and consequently our turkey allies have become very effective in beating off its attacks with relatively little loss, even while more or less constantly invaded by enemy forces. On the other hand, while our chickens bring to the campaign against Syngamus a relatively high species resistance to enemy invasion, they do not show that resistance in early life. Consequently chicks are likely to be destroyed by the enemy, partly because the relatively small trachea and bronchi of a chick can be rather completely blocked by these large enemies. Our strategy is primarily a matter of cutting the lines of communication between turkeys and chickens, so that enemy invasion of chicken areas is impossible. The protection of our turkey allies becomes a matter of manure disposal to prevent the return of enemy forces

as free larvae, or in earthworms which travel slowly but may carry forces over winter and cover no inconsiderable distance in the course of months. Wild birds may infect earthworms or convey gapeworms direct to poultry.

Group 10. Stephanurus. In kidneys, kidney fat, and other places; eggs pass in urine; no intermediate hosts; develop to third-stage larvae and are swallowed, or penetrate abraded and, sometimes, intact skin; all larvae wander.

Offensive weapons: None established; apparently little likelihood that any anthelmintic weapon effective against worms in kidney and kidney fat, will be developed.

Defensive weapons: The eggs and larvae of the swine kidney worm are readily destroyed by sunlight, heat and drying; they survive longest in such trash and litter as corn husks. Obviously, the best terrain for enemy operation is that afforded by a hog pen full of litter of all sorts, since this provides shade and moisture. While a pasture is less favorable, it will afford a satisfactory terrain for enemy operations in some places.

A campaign method which is being developed and tested at Moultrie, Ga., under the supervision of the Zoological Division is a modification of the swine sanitation system. Under this modification, a space about 15 feet wide at the side of a pasture is kept free of vegetation, and the A-type portable hog house and the feeding pen of the sow are on this cleared area; pigs are kept out of this feeding pen. The feeding pen of the pigs, to which the sow can not gain access, is on the cleared area. Observation shows that sows usually defecate and urinate in the vicinity of the hog house, and if an infected sow urinates on the cleared area the kidney worm eggs and larvae are destroyed by sunlight because of the lack of litter and protective vegetation in that area. The little pigs feeding on clean pasture and in a feeding pen on that area, are fairly well out of the danger zone and are likely to suffer but little injury from the enemy, if they suffer any.

Group 11. Habronema, Tetrameres. In lumen and lining of digestive tract; eggs pass in manure; intermediate hosts used; intermediate hosts swallowed by primary hosts in some cases, but probably not in all cases.

Offensive weapons: Anthelmintic weapons may be employed on the assumption that they will destroy enemy forces in the

lumen of the digestive tract and those that are not too well dug in, and will not destroy those that are well dug in.

Defensive weapons: The hostile forces of Habronema use flies as intermediate hosts. Most of these flies breed in horse manure. The use of the manure platform over a shallow concrete tank filled with water or a coal-tar creosote dip, as devised by the Federal Bureau of Entomology, affords strategic control by fly destruction, but does not give the same results in parasite destruction that the manure box gives, as the manure box destroys both flies and worms. To control biting flies which carry Habronema, burn the straw and litter in which these flies breed.

Tetrameres uses grasshoppers as intermediate hosts. The indicated lines of a campaign against Tetrameres are those of manure disposal and grasshopper destruction. Resort to grasshopper destruction would depend on whether their general destructiveness to crops in a given area outweighed their usefulness as food for chickens on range. Grasshoppers can be destroyed by the use of poison baits, the hopperdozer and other means.

Group 12. Intestinal tapeworms. In lumen of digestive tract; eggs pass in manure; terrestrial intermediate hosts used; larvae develop to adults without penetration but with attachment of head to lining of digestive tract; exceptionally, such forms as Dipylidium sometimes penetrate mucosa.

Offensive weapons: Anthelmintics selected for known efficacy; will sometimes fail with Dipylidium because this tapeworm may dig in and be out of range of anthelmintic weapon.

Defensive weapons: Such tapeworms as those of the genus Taenia, using mammals as intermediate hosts, can be attacked by such weapons as cooking to destroy their larvae, or by the destruction of infested viscera in the "condemned" tank in our meat inspection service. That service supplies one of the most effective weapons against parasite enemies of various sorts. Dipylidium uses fleas and lice as intermediate hosts, and an attack on these intermediate hosts, which have been discussed as external parasites, is indicated. The intermediate hosts of poultry tapeworms include many small invertebrates, and measures for cutting the lines of communication via these hosts, are not well worked out by the boards of strategy of the intelligence service. Screening is effective against some of these intermediate hosts, but not against all.

Group 13. Trichinella. In lumen of digestive tract as adults; eggs hatch *in utero,* and larvae wander to and encyst in muscles of primary host, the same primary host becoming the secondary host also; new hosts infected by eating flesh of previous primary-secondary hosts.

Offensive weapons: No weapon known to be effective, but an anthelmintic weapon is theoretically a possibility and may be developed.

Defensive weapons: This is a very special and interesting problem in tactics and strategy. Since man becomes infected by eating infested pork, the classical tactics of cooking pork well before eating, are employed against this enemy, and there are also certain lethal weapons, such as freezing and curing processes, which are employed in packing house procedures to destroy trichinae in pork products customarily eaten without cooking.

The above procedures are for the protection of man. How are we to protect our swine allies from the enemy? For years there has been more or less debate, and I have frequently indulged in it, as to whether swine were infected most often by eating the carcasses of infested swine, or by eating pork scraps, or by eating infested rats. It finally dawned on me that, regardless of what was true in this connection, our drive against the enemy lines of communication would be the same in any case. The tactical answer to the trichina problem is the same as the answer to the swine ascarid problem, the swine lungworm problem, and sundry other problems in campaigning against swine parasites, and that answer is the swine sanitation system.

If a farmer is sufficiently intelligent and industrious to use the swine sanitation system, the following results may be expected: His swine will not eat rats because the rats will remain around old buildings, corn cribs and similar places where rats find the sort of food they prefer; these rats will not go out on the pasture to any great extent, and will not die there or be caught there and eaten by swine. His swine will not eat infected pork scraps because they wlll not be fed swill or garbage. Finally, such a farmer will not leave swine carcasses lying around for other swine to eat. As a result of these things, the swine sanitation system will probably eradicate trichinae from the farms on which it is used, and if generally practiced over the United States would probably eradicate this enemy from swine in our

country, leaving the enemy to survive in another enemy, the rat, or to some extent in cats, if it survived at all.

Group 14.—Fasciola hepatica. In liver as adults; eggs pass in manure and hatch in water; first larva infects snails; resultant larva infects primary host when swallowed; larvae wander to liver.

Offensive weapons: An attack with a suitable anthelmintic weapon (carbon tetrachloride) may be launched by mouth to the intestine, where the blood stream will pick it up and direct it at the invaded area, the liver, in which area the weapon used will destroy the enemy forces; later attacks are usually necessary to destroy reinforcements from wandering forces reaching the liver from elsewhere in the body or from the outside.

Defensive weapons: In this group, as in group 16, snails are utilized as intermediate hosts, and snail destruction is a practical strategic measure of great value. Copper sulphate is a cheap and effective weapon for destroying snails. Large chunks or crystals may be placed in gunny sacks in the springs at the headwaters of small streams, and at points lower down. By damming the stream at intervals the sulphated water may be made to overflow snail-infested wet areas along the banks. Powdered copper sulphate, mixed with 6 to 8 times its volume of lime, landplaster or sand, may be broadcast on wet areas that can not be flooded, and along the banks of lakes, ponds and large streams. Small amounts of sulphate may be placed in drinking troughs where snails breed. Finally, the powdered material may be spread by airplane over large marshy areas. Wet areas often can be drained or filled to prevent the breeding of aquatic or amphibious snails, or, if they can not be drained or filled, they can be fenced off to keep livestock away from danger areas, and thus prevent a junction of the enemy forces with the snails that hold their only lines of communication.

Group 15. Bilharziella. Adults in blood; eggs pass in manure and hatch in water; first larva infects snails, and develops to larvae infective for primary host; larva penetrates skin.

Offensive weapons: Not well ascertained against this enemy group in our domesticated animals; tartar emetic, emetine and other drugs effective against similar enemies in man.

Defensive weapons: As for group 15. These blood flukes occur in ducks and geese and are present in the United States.

Group 16. Dirofilaria, Setaria. Adults in heart, body cavity, subcutaneous connective tissue, or other cavities and tissues; larvae in circulating blood are taken up by blood-sucking arthropods and develop to infective larvae in these intermediate hosts; primary host infected by the bite of secondary host in feeding.

Offensive weapons: Not yet established. It is probable that an effective anthelmintic weapon against Dirofilaria, at least when this enemy is present in its usual site in the heart or blood stream, will be developed. [See "Fighting the Cruel Heartworm," page 124.]

Defensive weapons: In this group, as in group 17, there are various possible lines of defense. One is a line of defense by attack, which, as noted, is in many cases the best defense. We can attack the parasite in its primary host, and here the attack may be of the order of complete destruction of enemy forces in all stages of development, or may be of the order of partial destruction, leaving either the adults alive after the destruction of larvae, or the larvae alive after the destruction of adults. If we leave the larvae, it is still possible for the enemy to travel to new and unoccupied host areas, but if we destroy the larvae we have cut the lines of communication via the secondary host. As yet we do not have the proven weapons with which to take any of these objectives, but we expect the intelligence service to develop them. [Subsequently developed; note date of this paper.]

Meanwhile, we have the possibility of cutting the enemy lines of communication by protecting primary hosts from the external parasites which carry the forces of the internal parasites. Dirofilaria is carried for the most part by mosquitoes, and here we can destroy mosquitoes, and can put our dogs in mosquito-proof kennels with self-closing doors to shut out the night-flying aerial enemy forces with their landing parties of filarid worms. Our long-haired dogs have the advantage over our short-haired dogs that they are not so easily reached and attacked by enemy air forces.

Group 17. Piroplasma, Anaplasma. Schizogenous generation in blood stream; stages taken from blood by blood-sucking arthropod intermediate hosts in which sexual development occurs (at least in Piroplasma), forming infective stages which at a later stage of development of the intermediate host are transferred to new mammalian hosts.

Offensive weapons: Attacks with certain drugs (trypan blue) launched intravenously are more or less effective against some (Piroplasma), but not others (Anaplasma), of these enemy forces.

Defensive weapons: As for 16, an attempt to obtain complete or partial destruction of enemy forces in primary host, or to destroy secondary host, or to keep secondary host isolated from primary host and thus cut the lines of communication of the enemy. [See pp. 44 and 99.]

Group 18. Coccidia. Sexual generation in tissues of host; certain stages pass in manure and undergo schizogenous development, forming stages infective for hosts.

Offensive weapons: None established as effective.

Defensive weapons: In general, the control measures against coccidian oocysts are similar to those against the infective worm egg, as discussed under 1, and are primarily matters of suitable manure disposal. An additional weapon against coccidia is the use of wire or hardware cloth for flooring chicken houses so that coccidia in droppings collect out of reach of poultry. Control by immunological methods and by suitable food factors is receiving attention from the intelligence service.

Group 19. Diphyllobothrium latum. Adults in lumen of the digestive tract; eggs pass in manure and hatch in water; first larva infects small crustaceans as first intermediate hosts, forming second larval stage; first intermediate hosts are eaten by secondary intermediate hosts, fish, and in these a third-stage larva forms; third-stage larva may be transferred from one fish to another when infested fish are eaten by other fish; final host infected when infested fish are eaten raw or insufficiently cooked; no wandering in final host.

Offensive weapons: Anthelmintics selected for known efficacy.

Defensive weapons: In the case of such a worm as the broad fish tapeworm, we have an unusual set-up in that our sewage disposal system, usually ideal for the destruction of worm enemies, provides a set-up very favorably to the enemy. This system automatically ensures that fecal matter containing the worm will go back to water, usually to streams or lakes. If the necessary intermediate hosts are present in this water, the danger from eating infected fish will be present.

An attack on the first intermediate hosts, copepods, does not

appear to be very practical at present, but so far as the secondary intermediate hosts, fish, are concerned, we can apply the general principle that well-cooked food may be eaten with safety; if we must eat parasites, and at times we must and do, it is wiser to eat them cooked than raw, and to eat them dead rather than alive.

As a summary, let us pick up these enemy regiments and groups, and place them on a war map in accordance with their habits, with a brief note on tactics and strategy applicable to them as arranged in this fashion. The war map, roughly sketched by the writer and put in its present form by Dr. J. E. Alicata, shows in diagrammatic fashion the various forms in which the enemy forces move from an occupied area previously captured, to invade new areas. Their lines of communication are shown to lie along the manure route for the most part, although a few will move out by way of the urine, and some by way of blood abstracted by intermediate hosts. The form of the enemy at the time of exit may be that of worm eggs or larvae, or oocysts or other protozoan forms. Once on the road the enemy organizes his forces for the offensive by developing infective forms capable of invading new areas. The lines of march diverge in many respects, some of them routing through an intermediate host or two or more such hosts, but ultimately they converge in attacks on our allies by way of the mouth or the skin. The map shows clearly the wide application of tactical procedures before the point of divergence, as in manure, or at the point of convergence, as in food and water. It also shows the special application of certain tactics directed against certain enemies in cutting their lines of communication.

A synoptical key to some of our common parasites, based on life history and showing briefly the control measures, is as follows:

Arthropod Parasites, Usually External

1. Occasional parasites, breeding off host. Mosquitoes, biting flies, etc. [Attacks center on breeding places off hosts.]

More or less permanent parasites, living on or in host in some or all stages—2.

2. Permanent parasites; eggs laid on host. Lice, mites, etc. [Insecticides are effective weapons; cut enemy lines of communication between occupied and unoccupied areas.]

Either non-parasitic as adults, or, if parasitic as adults, eggs not laid on host—3.

3. Parasites as adults; eggs not laid on hosts. Ticks and fleas. [Insecticides are effective weapons, but in case of fleas, enemy reserves in breeding places must be destroyed.]

Parasites as larvae; eggs usually laid on hosts. Bots, ox warbles, etc. [Attack larvae *in situ;* large-scale campaigns extending to total eradication appear to be only alternative to constant warfare.]

Worm and Protozoan Parasites Regularly Internal

1. Enemy movement from host to host begins by manure transport. [Manure box effective against all enemies in this bracket]—2.

Enemy movement from host to host does not begin by manure transport—16.

2. Enemy movement continued by return of infective eggs or oocysts to host. [Plowing manure under is effective against all enemies in this bracket]—3.

Enemy movement not continued by return of infective eggs or oocysts to host—4.

3. Larvae hatching from infective eggs after return to host do not wander or invade tissues so deeply as to be out of range of anthelmintic weapon. Trichuris, Ascaridia, Heterakis. [Anthelmintic weapons effective against enemy; unnecessary to wait for enemy reserves to come into line of fire; repeated attacks necessary against Trichuris and Heterakis because of location, or Heterakis may be subjected to rear attack.]

Larvae hatching from eggs after returning to hosts, or sporozoites from oocyst, wander out of range of anthelmintic weapons. Ascaris and related genera, and coccidia. [Anthelmintic weapons effective against worm enemy; necessary to wait for enemy reserves to come into line of fire. No effective offensive weapons developed against coccidia.]

4. Enemy movement continued by direct return of infective larvae to host. [Plowing under not dependably effective; pasture rotation of value.]—5.

Enemy movement continued by use of intermediate host—9.

5. Larvae do not wander out of range of anthelmintic weapons. Haemonchus, Nematordirus, Ostertagia, Cooperia. [Anthelmintic weapons effective against enemy; unnecessary to wait for enemy reserves to come into line of fire.]

Larvae wander out of range of anthelmintic weapons—6.

6. Adults develop in lumen of digestive tract in range of anthelmintic weapons. Ancylostoma, Uncinaria, Strongyloides, Strongylus, Oesophagostomum. [Anthelmintic weapons effective; must be timed to await enemy reserves coming under fire, or repeated attacks made where we do not know time reserves come up.]

Adults do not develop in lumen of digestive tract, or only part of them do so—7.

7. Adults develop in lumen and lining of digestive tract. Habronema, Tetrameres. [Anthelmintic weapons of value, but only partially effective.]

Adults develop in locations other than digestive tract. [Anthelmintic weapons generally ineffective or inadequately developed.] —8.

8. Adults in air passages of lungs; intermediate host sometimes used; Syngamus. [Surgical weapons.]

Adults in air passages of lungs; intermediate host never used. Dictyocaulus. [Nursing treatment.]

9. Land snails used as intermediate hosts; adults in lung tissue or air sacs; Synthetocaulus, Muellerius. [No effective anthelmintic weapons; destroy snails by spraying or dusting with copper sulphate.]

Land snails not used as intermediate hosts—10.

10. Earthworms used as intermediate hosts. [Plowing manure under is undesirable.]—11.

Earthworms not used as intermediate hosts—13.

11. Manure-breeding earthworms used as intermediate hosts. Metastrongylus. [No effective anthelminitc weapons. Swine sanitation system used to prevent junction of enemy forces.]

Manure, soil and pasture earthworms used by intermediate hosts—12.

12. Intermediate hosts not always used. Syngamus. [Surgical removal.]

Intermediate hosts always used. Chicken tapeworm, *Amoebotaenia sphenoides*. [Anthelmintic weapons more or less effective for removing strobilae, but not heads.]

13. Mammalian intermediate hosts used. Tapeworms of genus Taenia and related genera. [Anthelmintic weapons effective; cook flesh of intermediate hosts used as food, or destroy infested viscera.]

Mammalian intermediate hosts not used—14.

14. Insects used as intermediate hosts. Certain poultry tapeworms and Dipylidium. [Anthelmintic weapons more or less effective against Dipylidium; certain insect hosts can be destroyed.]

Aquatic or amphibious intermediate hosts used—15.

15. Amphibious or aquatic snails used. *Fasciola hepatica,* Bilharziella. [Anthelmintic weapons effective against Fasciola; repeat attacks as enemy reserves come under fire. Destroy snail hosts.]

Copepods and fish used as intermediate hosts. *Diphyllobothrium latum.* [Anthelmintic weapon effective. Cook fish thoroughly before eating or feeding to primary host.]

16 Enemy movement from host to host begins by urine transport; larvae wander and develop to adults out of range of anthelmintic weapons. Stephanurus. [No effective anthelmintic weapons. Modified swine sanitation system used to cut enemy lines of communication and transport.]

Enemy movement from host to host does not begin by urine transport.

17. Primary host also serves as intermediate host. Trichinella. [No effective anthelmintic weapons. Cook pork thoroughly. Use swine sanitation system.]

Primary host does not serve as intermediate host—18.

18. Worm larvae in circulating blood; taken up by biting arthropods; returned after development to primary host. Dirofilaria, Setaria. [No effective anthelmintic weapons developed. Guard against intermediate hosts, such as mosquitoes.]

Schizogenous generation in circulating blood; taken up by biting arthropods; returned after development to primary host by bite of arthropod, but in later stages of arthropod's development. Piroplasma, Anaplasma. [Offensive weapons partially effective in some cases. Destruction of tick hosts cuts some enemy lines of transport.]

WAR MAP OF CAMPAIGNS AGAINST PARASITES

Infective stage taken from blood by → Mosquitoes (11) → Subsequent infective stage transmitted by biting

Infective stage taken from blood by → Ticks (12) → Ticks molt → Later tick stages transmitted by biting

Skin, Blood, Lungs (13), Mouth, Kidney, Bladder

Infective material in manure (1) → On soil (2) → Becomes infective (3) → Infective egg or oocyst (15) swallowed (4)

Domesticated host animal

Infective material in urine → Form infective larvae (10)

Eggs hatch → Form infective larvae (2, 15)

Form free-living adults → Eggs → Infective larvae (2, 15, 16)

Lungworm larvae → Form infective larvae (2, 15)

Eggs swallowed by secondary host → Infect secondary host → Snails swallowed (5, 14)

Eggs hatch in water → Larvae infect secondary host

- Earthworms swallowed (1)
- Flies (6) → swallowed or attack
- Grasshoppers swallowed (7)
- Flesh or viscera eaten (8, 9)
- Infective larvae (5) → swallowed or attack
- Copepods swallowed by → Fish eaten by other fish (8)

Fish eaten → To mouth

To skin

Rat or Swine — Trichinae in Flesh — Swallowed by swine (8) — Muscles — Trichinae in Flesh — Swallowed by man (9) — Muscles

Skin, Blood, Lungs, Liver, Other viscera, Nodule, Kidney, Blood (13)

Domesticated host animal

WEAPONS

1. Manure box
2. Rotation
3. Plowing under
4. Swine sanitation
5. Snail destruction
6. Fly destruction
7. Grasshopper "
8. Cooking food
9. Meat inspection
10. Modified swine sanit.
11. Mosquito destruction
12. Tick dipping
13. Anthelmintics
14. Feeding of bonemeal, etc.
15. Light stocking
16. Bare lot

J.E. Alicata, del.

Anthelmintic Warfare*

Anthelmintic medication may be regarded as a form of warfare against worms, and the medical man, be he physician or veterinarian, may be likened to an officer in command. As such he must be versed in the tactics and strategy of this form of warfare. As naval officers, you may find an extension of this simile of interest in connection with this medical topic. The weapons of warfare in general are those causing traumatic injury, toxic injury, and such physiological conditions as starvation, asphyxiation, etc. Traumatic attack on worms is possible in certain cases. Surgical intervention, as in the removal of hydatids, cysticerci, oncocerca tumors, guinea worms, etc., is feasible and is commonly practiced. Starvation and asphyxiation cannot well be employed against worms. The common ascarid of man and swine can live as long as 26 days in Kronecker's solution, a slightly alkaline physiologic saline solution, and there is little hope of starving such a worm within its host. The conditions under which many worms live may be termed practically anerobic for animals, so there is little likelihood of our being able to asphyxiate these worms. The vast majority of our weapons of warfare against worms fall into the category of those producing toxic injury.

Under the conditions of warfare against worms the enemy (the worms) must be driven from a terrain which may be likened to the invaded territory of a friend and ally (the host), and we must at all times keep in mind that the destruction of this enemy must be accomplished with the minimum of damage to the occupied territory. In other words, our toxic weapon (the anthelmintic) must cause the maximum injury to the worms and the minimum amount of injury to the host. Our warfare must be carried out in the dark against an unseen enemy. We launch an attack and judge its results by the evidences in the form of enemy casualties (worms passed in the feces) or in the form of cessation of enemy activity (cessation of egg production by blood flukes) or in indications of diminished enemy activities seen in the invaded terrain (clinical improvement of patient). On the basis of an initial attack we may announce a complete victory or declare the attack a failure or only a partial success and launch a second or a third attack.

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Fortunately, we may adopt training camp methods in studying anthelmintic warfare. We need not hurl a poison gas of unknown capacity for injury to friend or enemy into the occupied friendly terrain. By the method of animal experimentation we can obtain very definite and useful information in regard to the efficiency and safety of our weapon. We can launch an attack, collect the casualties, and by post-mortem examination we can uncover the scene of action and ascertain the survivors. In rare instances human subjects, criminals condemned to death, can be used in this way, and this has been done on several occasions in tests of carbon tetrachloride, but in general we must depend on the method of critical test on experimental animals for our information as to the exact efficacy of drugs. In veterinary medicine the findings with this method apply at once and with little modification to veterinary practice. In human medicine the findings on experimental animals, such as dogs, require some modification in transfer to the case of the human being, but this does not alter the fact that the training-camp method of animal experimentation is of great value in the warfare against worms in human beings. This training camp method has done much in the last 10 years to make our armamentarium of anthelmintic weapons among the most dependable of all the weapons the physician possesses in the field of war against disease.

In anthelmintic warfare the commanding officer must have a sound knowledge of the many involved factors. He must know his weapons, the anthelmintics, and this involves a knowledge of their efficacy, safety, minimum effective dosage, minimum lethal dosage, solubility, concomitant effects, relation to purgation or constipation, and to specific purgatives, etc. He must know his enemies, the worms, and this involves a knowledge of their sites, habits, life histories, etc. Finally, he must know the field of action, the patient, and this involves a knowledge of the patient's physical condition, possible contraindications for treatment, such as profound weakness, massive infestations with ascarids in very weak patients, cirrhotic livers or pronounced pathological conditions of the kidney where drugs seriously affecting these organs are to be used, alcoholism, etc. The well-informed officer will know these things and will select his weapons and plan his campaign with these in mind, and will in consequence carry on successful campaigns, come victorious from his battlefields, and will

have few casualties among his allies, the patients. The officer who neglects his study of anthelmintic tactics and strategy will select his weapons without judgment, enter his campaign without plans, will fail to take his objectives, and will inflict disproportionate losses on his allies.

The modes of attack with anthelmintic poisons are quite varied. One may employ a frontal attack by oral medication, launching the attack by floods in solution as a drink or by stomach tube or in other ways, or by shells in the form of hard or soft gelatin capsules. This is the common mode of attack for worms in the stomach or small intestines. For worms in the small intestine one might use an anthelmintic explosive shell in the form of an enteric-coated capsule which would not open in the stomach, but so far it has been difficult to time these shells to open at the right point, and they are likely to pass the enemy unopened and explode in the rear, inflicting no damage on the enemy and at least slight damage on the allied terrain. Such a frontal attack may fail if the enemy has dug in by burrowing in the mucosa or under a catarrhal exudate. In this attack one must pay attention to the attack by purgation as well as to the preparation for the attack by fasting. The question as to whether the purgative should go over the top with a given anthelmintic or follow it as a mopping-up party is a very important one. The purgative has the dual function of assisting the anthelmintic attack and protecting the terrain against injury by the anthelmintic. At present the tendency in practice, supported by experimental evidence, favors a simultaneous attack by anthelmintic and purgative, or at least a prompt launching of the purgative attack, in the case of most anthelmintics. As regards fasting, it seems likely that allowing the patient a light meal in the evening and attacking the worms the next morning is ample preparation for the purposes of the attack and less weakening to the patient than more prolonged fasting.

A rear attack by the use of enemas is indicated in the cases of certain parasites in the lower part of the digestive tract. It is commonly employed in the removal of the gravid female pinworms in the colon.

A flank attack may be made in the form of subcutaneous, intramuscular, and intravenous injections of anthelmintics, or of anthelmintics given by mouth and attacking by way of the blood,

etc., and this form of attack has received much consideration of late years and has become extensively used in certain cases. Thus tartar emetic and emetine are commonly used by intravenous injection against blood flukes, tartar emetic and novarsenobenzol have been used successfully against the guinea worm, sugar in large amounts by mouth is reported as effective in removing the guinea worm, male fern is effective in removing the common liver fluke from the bile duct of sheep and cattle, and Lambert has reported the removal of whipworms from man by means of intravenous injections of chenopodium and to a lesser extent by the use of intramuscular injections of chenopodium. This mode of attack is very interesting and will doubtless receive much more attention in the course of time.

A final consideration in this survey of the strategical aspects of anthelmintic medication is that of prophylaxis against worm infestation. Prophylaxis is a form of warfare by which the enemy is cut off from reinforcement, the allied terrain being surrounded by sanitary conditions favorable to the terrain and unfavorable to the enemy, which is prevented from obtaining additional forces. In pinworm infestations this is of great importance, as the great difficulty here appears to be the constant accretion of forces by renewed infestation. If the infestation can be held down and kept without renewals, even the slow gnawing or nibbling process, the wearing down of the enemy a little at a time, coupled with the enemy losses due to causes other than losses in battle, such as deaths from age, disease, and other factors, must ultimately clear the invaded terrain of the hostile forces.

Just as research on the subjects of explosives, poison gases, and firearms is a constant occupation of times of peace, so investigations of anthelmintic efficacy and safety is a laboratory task that must prepare for the campaigns of mass treatment in tropical and subtropical countries and for the minor engagements of private medical practice. The old armamentarium of anthelmintics established by clinical use, and often originating in ancient folk practice, must be studied by critical tests, checked by post-mortem examinations, and the true efficacy and safety rather definitely ascertained. Chemicals not in use as anthelmintics, but promising in this connection on theoretical grounds, must be similarly tested. Underlying our experimental findings there are certain fundamental principles which when once known and understood will en-

able us to improve our anthelmintic weapons with greater speed and certainty. Such tests as have been made have established certain of the older anthelmintics as effective and reasonably sure in suitable doses against certain worms. Thus chenopodium has been established as effective against ascarids and the Old World hookworm, *Ancylostoma duodenale*. New anthelmintics have been similarly established as effective for certain purposes. Thus carbon tetrachlorid has been established as effective against the New World hookworm, *Necator americanus*.

A study of enemy movements, in the form of a study of the life histories and habits of worms, has given definite information in regard to plans of battle against worms, both along the lines of anthelmintic warfare and of sanitation against worms. We know that many worms enter the skin of the host, or enter the wall of the digestive tract after being taken in by the mouth, and that these invaders may wander through the circulation, tissues, and air passages of the host for days or weeks before occupying the lumen of the digestive tract, their final objective. We know that during these maneuvers, these enemies can not be successfully attacked. A campaign of extermination against these enemy forces should, therefore, include plans for host sanitation for a period before anthelmintic attack. Failing this, the attack may clear out the enemy forces present in the digestive tract, only to have the migratory forces occupy the scene of battle, perhaps in force, for days or weeks afterwards, necessitating a renewed attack with its concomitant injury to the host. In this connection we know that prenatal infection may occur with worms of migratory habits, and that if we are to protect the fetus and the infant from attack, sanitary measures for the mother must be established early in the embryonic life of the offspring.

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